Form 9-014

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

A RECONNAISSANCE

of the

GROUND-WATER RESOURCES OF THE

CONNECTICUT RIVER BASIN

Prepared in cooperation with

U.S. ARMY CORPS OF ENGINEERS

New England Division

ADMINISTRATIVE REPORT

☆ U.S. GOVERNMENT PRINTING OFFICE: 1962—O-632210

A RECONNAISSANCE

of the

GROUND-WATER RESOURCES OF THE

CONNECTICUT RIVER BASIN

By

D. J. Cederstrom

Hydrologist

U. S. Geological Survey

Prepared by

U. S. GEOLOGICAL SURVEY

Water Resources Division

In cooperation with

U. S. ARMY CORPS OF ENGINEERS

New England Division

June 1966

Administrative Report

CONTENTS

Page

FIGURE

APPENDIX E

GROUND WATER RESOURCES ~~OF THE CONNECTICUT RIVER BASIN~~

all caps

I Introduction

This report was written as part of a cooperative project between the U.S. Army Corps of Engineers and the U.S. Geological Survey and is one facet of an overall investigation of the water and related land resources of the Connecticut River basin made under the leadership of the Corps of Engineers. The purpose of the report is to show where and how much ground water is available throughout the Connecticut basin, from the Canadian border to Long Island Sound, an area of about 11,000 square miles. Funds allotted provided for about a year and a half of the writer's time, about half of which was spent in the field, and a little more than a year's time for his assistant Arthur L. Hodges, Jr., most of whose time was spent in the field.

It is clearly evident that the total quantity of ground water available in the basin is very large, perhaps more than one billion gallons a day in all. However, a fairly accurate, complete, and detailed determination of the ground-water resources of the Connecticut basin can only be accomplished in terms of many man-years work and hundreds of thousands, perhaps a few million dollars. Inasmuch as time and funds were less than those indicated as necessary for a thorough study, the question arose as to what might be done within the prescribed time limits and with funds available that would best serve the purposes of the study. The attitude was taken that a summary would be made of certain gross features that would show clearly the order of magnitude of ground-water supplies in the basin, where these were located, and to a limited extent, how these could be developed. The need for additional studies of various types and in specific localities would then become apparent from the point of view of optimum production of the ground water supplies throughout the area.

In the Connecticut basin, large ground-water supplies may be withdrawn from the ground only from sands and gravels deposited by meltwaters in the waning stages of decay of the continental glacier (glacio-fluvial deposits) and from recent river alluvium. Therefore, it was obvious that the first order of priority should be a map showing the areal distribution of those formations. Well over half the total time allotted to the project was given to preparation of such a map. The map ~~will be~~ is published ~~separately~~ and attached as a Hydrologic Atlas.

Areas where large supplies should be available are delineated on the map as are areas of unconsolidated sediment that are less favorable or unfavorable for development of ground water. The map is, therefore, a ground-water favorability map that is indicative of quantities of water available in the general terms.

To give a reasonable substance to the study in quantitative terms it was found highly desirable to describe briefly every area of glacio-fluvial sediment in the Connecticut basin from the point of view of volume of ground-water available. These evaluations are necessarily highly generalized and in no sense should they be compared with quantitative studies as commonly understood. For instance, an outstandingly fine quantitative study was recently made of the CANEL site below Middletown, Conn., an area of a few square miles. Almost a year was spent on the study and involved the time and abilities of three scientists. High-yield wells were available for pump testing and thirteen other wells were available in the area for observations of various kinds. The cost of the CANEL study exceeded the funds available for this study. With this in mind, it becomes immediately apparent that the evaluation presented in the following report can only represent reasonable estimates based on certain valid assumptions and the experience and judgment of the writer. Nevertheless, a rather considerable number of helpful quantitative evaluations are presented that will be of interest to city managers, industrialists and others who are desirous of developing well water supplies in large quantity. It is not implied that the ground water in any area is the only water available there or that it is the best source of water. Potential water users will, of course, acquaint themselves with all sources of water that might be made available, either in the area of use or at some more distant point, and decide what is the best development for their needs.

The assessments made are necessarily based on reasonably well established hydrologic assumptions, comparison with other similar but better known areas and the investigators' ability to reconstruct mentally the 3-dimensional geology based on scanty specific data and in many instances on no data at all other than what may be seen on the surface. The assessments, then, reflect the writer's judgment to a large degree.

As explained below, that part of the total precipitation that enters the ground and recharges the ground-water reservoir is equal to about 1 mgd (million gallons a day) per square mile where the earth material is unconsolidated sandy sediment. Where the earth material is largely consolidated rock, recharge to the ground-water reservoir is of the nature of one-third of a million gallons a day per square mile. Thus in some unit areas a very simple assessment may be made of the amount of ground water that may be pumped continuously. For instance, in a number of sediment filled valleys in which no significant stream is present, it may be said with reasonable certainty that up to 1 mgd should be available per mile along the length of that valley. Such a statement is, without exception, based on the assumption that geological formations are present that will permit infiltration of precipitation upon the surface and that formations at moderate depth are such that high yield wells may be constructed.

Where an area of permeable sediments receives recharge from outside that area via small streams the assessment is still not difficult. The drainage area of the streams that enter the area in question is similarly evaluated and added to the initial evaluation. Here it must be assumed or determined that stream water will not be prevented from infiltrating the ground by near-surface impermeable formations or perhaps it must be decided that water from the adjacent area can enter by underground flow. Again the evaluation might be considered excellent pending future test drilling and detailed studies.

In either of the situations considered the probable volume of underground storage must be considered. Where the volume of alluvium in a valley is small, a high yield well might be constructed but a high discharge could be maintained for only a very short time. In large part, the rate of discharge would depend on the recharge that the alluvium had received in the preceding few days or weeks. However, where a large volume of storage is present, storage water could be "borrowed" by the wells in a long dry period pending replenishment of the reservoir in a succeeding wetter period.

Where potentially large supplies of ground water are considered, as in wide sandy areas crossed by large or small rivers the problem is more difficult. It is obvious in many instances that large supplies are available but the question is, how large. The problem is complex and cannot be answered without the expenditure of time and money. Available well records may or may not show that permeable sediments in which high yield wells can be constructed are widely distributed. Recharge from local precipitation can be evaluated but without suitable tests the contribution to the ground water reservoir from a large stream or river can only be guessed at. Streamflow studies would show that a certain large volume of water is generally available from recharge. However, the rate at which available streamflow will infiltrate the ground under heavy pumping conditions depends upon the character of the geological formations present, the degree of clogging of the river bed and other factors that can only be determined by pump testing at any particular locality at various stages of the adjacent river. The ground water increment to the stream (a large fraction of the volume of base, or fair weather, flow), is not the only portion of total flow that might enter the formation. A well field along a river might continuously discharge a volume of water greater than base flow (or greater than that part of base flow that can infiltrate the ground) if considerable underground storage is present. Discharging wells would then be able to draw upon this underground storage in periods of generally low flow and rely upon higher flows to make up the loss of storage incurred.

Thus, in the areas of high potential yield characterized by widely distributed glacial sediments whose thickness may exceed 200 feet in places and traversed by major streams or rivers, where infiltration will occur more or less readily, it may not be possible to say more than that the area is favorable for large ground-water developments and the potential yield is in excess of, say, 7 mgd, or that full development of ground water resources should be reckoned in tens of million gallons a day.

Summarizing, the estimates of quantities of water available where those supplies are rather small may be as accurate as any that might be made before developing the area by wells whereas estimates of larger supplies are orders of magnitude but which are, in a great many instances sufficient to show municipal officials and others that the ground water resources in particular areas should be generally available for anticipated needs. Further, where supplies are indicated to be potentially large, the upper limits of the estimate given are indefinite. For instance, where it is stated that 15 mgd should be available in some locality, the figure given is considered to be a conservative estimate and the total supply available might well be much greater if certain factors, assumed to be essentially unfavorable, are later determined to be favorable.

In summary, figures on the amount of water available are considered to be somewhat conservative in most instances and should not be considered as absolute limits of ground water development, particularly in areas where rapid infiltration from adjacent rivers may be possible. For instance, along certain streams the writer has assumed that a little recharge from that stream would almost certainly occur along a 10-mile reach. However, if it should be found upon testing and installation of production wells that infiltration from the stream occurs readily, the potential of the area might be much more than the figure given in this report. Inasmuch as the assessments of ground water areas are dependent in large part upon judgement, some "errors" will be made. It is felt that in a few instances the assessment may be found to be slightly high but in many more instances, the assessments will be found to be ridiculously low.

all copy center of new page

start new page

II Gross estimate of available storage and recharge

In Connecticut, (Randall, (1964b, p. 76) reference #9) (1) calculated that part of the flow of Salmon Brook in the Farmington-Granby area attributed to ground water runoff that drained half upland and half alluvial lowland was about 1 cubic foot per second per square mile. Ground water runoff is that part of streamflow that is derived from seepage from the ground-water reservoir. Therefore, the groundwater runoff of a river divided by the square miles of drainage area of that river is an index of the amount of precipitation that enters the ground and reaches the water table and hence nearly the maximum volume of water derived from local precipitation that is available to wells. However, more than "normal recharge," as measured in this fashion, may be available under a variety of circumstances. In an area where water levels are

(1) ~~Refer to~~ Reference #9 in Bibliography Section on Page E-

close to the surface, heavy pumping will lower the water table and evapotranspiration will be reduced and the water thus salvaged added to the total arrived at by calculation of ground water runoff from that square mile. In a heavily pumped area near a stream, water levels may be drawn so low that wells will capture not only the normal ground-water seepage to the stream but a little or much of the streamflow passing by may be drawn into the ground in the vicinity of the pumped wells. In considering what portion of streamflow might be thus captured, the most that can be done in this study is to indicate that scanty data suggest that infiltration may occur with ease or, conversely, sediments between the proposed pumping wells and a major source of recharge are fine grained and recharge may be poor.

In swampy areas, some recharge from local precipitation is rejected because the water level is at the surface. If water levels were lowered in such areas, additional recharge would take place, providing there is a good hydraulic continuity between the swamp deposits and the underlying aquifer.

As noted, Randall[2] calculated ground water runoff in the Farmington-Granby drainage area to be about 1 cfsm (cubic feet per second per square mile). (LaSala, ~~1964, p. 48~~ reference #5)[3] calculated base flow of the Pequabuck basin plus the underflow in the river bed to be about 1.17 cfsm. The Pequabuck drainage basin like the Salmon Brook basin includes much alluvial ground. Since the ground water runoff of Salmon Brook and the Pequabuck, about 1 cfsm, was determined on streams that drain areas partly underlain by rock and partly by sand and gravel, it might be concluded that ground water runoff from an area that is entirely covered by sand and gravel would be about 1.5 cfsm; roughly 1 mgd per square mile.

(2) Ibid
(3) ~~[illegible]~~ Reference #5 in Bibliography Section on Page E-8

Data supplied by J.A. Baker (communication, May 19, 1966)[4] show that the long term average annual recharge in a stratified drift area in the Quinebaug basin in Connecticut ranged from 1.00 to 1.15 mgd per square mile.

The present writer made calculations of ground water runoff of West Branch of Westfield River (Huntington, Mass. station) for years 1950-51 and 1956-57 and obtained 0.52 and 0.48 cfsm. West Branch of Westfield River lies in an area underlain in very large part by consolidated rocks.

A calculation made on the 1956-57 hydrograph of West River at Jamaica, Vt. indicated a recharge factor of 0.7 cfsm. A few sediment filled stream valleys are present in this drainage basin, especially in the vicinity of Londonderry, Vt.

The White River basin in Vermont is an area underlain in large part by rock but in which there are also several fairly long alluvium filled valleys upstream. Based on the 1955-56 hydrograph, recharge was estimated to be almost .8 cfsm.

For gross estimates then we may consider that recharge from local precipitation in an area that is underlain in largest part by consolidated rock is about .5 cfsm or 1/3 mgd per square mile.

The area covered by glacial silt, sand and gravel in Vermont and New Hampshire is estimated to be about 700 square miles (10% of total area in those states) and 300 square miles in Massachusetts and Connecticut (30% of the area in those states). Recharge normally averages about 1 million gallons a day per square mile; hence the recharge to the glacial water bearing sediments may be more than one billion gallons a day. In the following section dealing with water

(4) [Leave room for footnote]

in the sub-basins, it is indicated that a total of more than 600 million gallons a day can probably be developed in the basin as a whole by high yield wells. This lesser figure indicates that about a third of the area of unconsolidated sediments will yield water in somewhat small quantities or that sufficient storage water is lacking in many areas to sustain well discharge during extended periods of deficient precipitation.

Well discharge based on assumed or estimated average volumes of local recharge or induced infiltration from adjacent streams, or both, cannot be maintained during a drought year or during the driest part of any year unless there is ample underground stored water to draw upon during the periods of low recharge. The specific yield (available storage water) of clean, well-sorted, sandy, sediments may, for most purposes, be considered to be about 25 percent of their volume. Silty sand or fine sand has a specific yield of about 10 percent. Crystalline rocks such as granite, schists and gneiss, have a specific yield of about 1 or 2 percent derived from fractures.

The available stored water (specific yield) in 1 square mile of well-sorted sand or gravel 100 feet thick is (27,878,400 sq. ft x 100 x 7.48 x 25%) 5,213 million gallons. However, where the alluvial material is silty, it must be assumed that available storage water is less, perhaps about 2 billion gallons per square mile of section 100 feet thick.

A comparable volume of fractured crystalline rock would yield only 208 million gallons of storage water upon lowering water levels 100 feet.

In the discussion of some of the specific localities which follows, the estimated amount of available storage in a 50-foot thickness of sediment is given. In so doing, the writer assumes that the regional water level will be lowered not more than 50 feet below the surface. To draw the water level down that amount over any wide area would require that the pumping level in practically all wells be greater than 50 feet, perhaps considerably more. Hence, the figure given for available storage water is thought to represent the maximum that would be available at a reasonable pumping cost.

Storage water is water that can be drawn upon for a limited time, a few days, or weeks, or, depending on volumes involved, for a few years. Eventually, however, storage must be made up and a well development discharging more than the average recharge to the aquifer will sooner or later begin to fail to some extent. In calculations of recharge, it is to be borne in mind that recharge may include not only precipitation that infiltrates the ground locally but it also includes that portion of streamflow originating outside the area that may be drawn into the ground in the vicinity of pumping wells.

Lastly, it should also be borne in mind that pumping from the ground will subtract an equal amount of water, or nearly an equal amount of water from the flow of the stream draining the well field unless, by one means or other, the water is returned to the drainage system after use. In many instances, water will be treated after use and returned to the drainage system, or merely returned without treatment, and the net loss will be small. Where once-utilized water is returned in contaminated condition, the addition of such bulk contaminant to the stream may require that streamflow be maintained at higher levels than before the contaminant was added, in order to assure reasonable dilution. However, this is a problem to be faced in use of either surface water or ground water.

Where large supplies of ground water are developed in essentially small basins and that water is transferred for use into a different drainage area, streams in the well field area may be diminished in total flow and small streams may go completely dry except in periods of heavy rainfall.

Salinity of lower Connecticut River

The quality of ground water will be affected by the quality of adjacent surface water that recharges it. Hence, the salinity of the lower Connecticut River may affect the utility of well water supplies where wells are located close to the river and pumped heavily.

Studies of salinity variations of water in the Connecticut River were made from October 1934 through June 1939 as a Works Progress Administration, Connecticut State Water Commission and U.S. Geological Survey project (Meade, Robert H., p. 567). The term "salinity" as used in the study referred to above, is chloride content in parts per thousand. Thus 1 part of "salinity" will indicate that about 1,000 parts per million of chloride are present.

Figure 1 shows diagramatically the salinity of river water at several stages of flow. Average discharge of the Connecticut River is said to be 560 m^3/sec. At a flow of 907 m^3/sec (measured the previous day at Thompsonville, Conn.) the river is appreciably saline only at Saybrook but at progressively lower flows saline water migrates farther and farther upstream. During very low flow, 57 m^3/sec, 10 parts per million of chloride was detected about 2 miles below East Haddam bridge.

GROUND WATER RESOURCES OF THE SUB-BASINS

Sub-basin A

Sub-basin A is in the northernmost portion of the Connecticut River basin and includes the area drained by Indian Stream, Halls Stream, Mohawk and Nulhegan Rivers as well as the northernmost reach of the Connecticut River itself. That portion of the sub-basin A that lies in Canada is not considered here.

In the vicinity of Black Lake, N. H., (Indian Stream, N.H.-Vt., topographic sheet) glacio-fluvial deposits (sands and gravels) are present northeast of that lake. As much as 1 mgd (million gallons a day) may be available from wells penetrating those deposits. At Pittsburg, N.H. coarse fill from which ground water can be developed is present at and just east of the town. Assuming that aquifers are readily recharged from the Connecticut River, upwards of 1 mgd might be developed here with ease. Unconsolidated sediments are widespread along the lower two-mile reach of Indian Stream. Up to 3 mgd might be developed from wells located near the junction of that stream with the Connecticut River. Ground water is reporte to be irony at Black Lake and Pittsburg.

Sand terrace deposits are irregularly developed along the left bank (U.S. territory) of Halls Stream for a distance of about 7 miles above its junction with the Connecticut at Beecher Falls, Vt. It seems likely that 5 to 10 mgd could be developed from several wells spaced along the stream. Eskers, sinuous ridges of coarse sediment formed in streams that flowed beneath stagnant glacial ice, along Halls Stream may be the better sites for wells, particularly if the surrounding beds are fine grained.

Along the Nulhegan River in Vermont permeable gravels are present and known to be as much as 125 feet thick a few miles above North Stratford, Vt. (Averill, Vt.-N.H. topographic sheet). The reach for about 6 miles above North Stratford should be particularly favorable and perhaps 5 to 10 mgd could be developed in that area.

According to Earl Shurtleff, driller, thick permeable gravels are present at Island Pond airport (Island Pond, Vt., topographic sheet) a few miles east of town. Development of ground water in large quantity may be possible along most of Nulhegan River. The recharge area is large and the greatest problem would be locating deeper permeable gravels in which high-yield wells could be developed.

A well only 35 feet deep along the main stem at Beecher Falls, Vt., on the upper Connecticut River yields 230 gpm (gallons per minute) with 8 feet of drawdown (specific capacity of almost 40). In the one mile reach of stream above Beecher Falls (Indian Stream, N.H.-Vt., topographic sheet) wells located where they will penetrate the maximum thicknesses of gravel present and spaced to avoid interference might develop more than 10 mgd, relying upon the Connecticut River to recharge the ground-water reservoir under heavy pumping conditions. Naturally, any such large development should be preceded by test drilling to assure that the wells constructed will be of maximum efficiency.

Sandy sediments in the lower reaches of Bishop Brook (Dixville, N.H., topographic sheet) may be capable of supplying one-half mgd or more.

There is reason to believe that yields up to one mgd per individual well might be developed along the reach along the Connecticut River from

Beecher Falls to North Stratford (Averill, N.H.-Vt., topographic sheet) if wells are located out on the valley floor. Coarse gravels are seen along this reach, particularly on the east bank, in many places. Small tributary streams have built up minor deltas at Oblate Fathers Novitiate, Cones and Tinkerville, N.H. These deltaic areas are probably underlain by sediments coarser than elsewhere. The deltaic area around Colebrook may be especially productive of ground water. A coring taken on the New Hampshire side of the Connecticut River bridge at Colebrook shows that the section was somewhat silty to a depth of 26 feet and largely fine to medium sand to 67 feet. Sediments might well be coarser in the vicinity of Colebrook itself at the mouth of Mohawk River.

The maximum amount of ground water that might be developed along the Connecticut will depend on locating permeable gravels that are susceptible to recharge by the Connecticut River. Several million gallons a day might be developed at any one of many places along this reach of the Connecticut but to do so at any particular site it may be necessary to drill 3 or 4 test holes in an east-west line (across the valley) to determine the location of the best aquifers.

The Mohawk Valley (Dixville, N.H. topographic sheet) is sharply incised and it is thought that high yield wells cannot be developed there.

Summarizing, the larger supplies of ground water are available along Halls Stream, along Nulhegan River for about 6 miles above North Stratford, and along the Connecticut River from above Beecher Falls and southward to North Stratford. The area around Colebrook at the mouth of Mohawk River may be particularly favorable. In uppermost New Hampshire ground water potential is much poorer. Along Mohawk River little or no ground water supplies can be developed from glacial deposits.

Sub-basin L-1

Sub-basin L-1 includes the area along the Connecticut River from North Stratford, Vt. to Dalton N.H., that is drained by several small streams and by Johns River. However, the Upper Ammonoosuc and Israel River drainage systems that discharge in this reach are excluded.

The low flood plain area along the Connecticut River, from North Stratford to Dalton, is filled to a large extent with fine silt and clay and ground-water potential is poor. For example, drilling data show that a mile above Guildhall, Vt., (Guildhall, Vt.-N.H., topographic sheet) 120 feet of clay lies upon bedrock. West of Lancaster, N.H., (Whitefield, N.H.-Vt., topographic sheet) silty clay was penetrated to a depth of 160 feet in one place.

Between North Stratford and Groveton, N.H., patches of coarse sediments are present along the east bank, some of which are miniature deltas. If these sediments extend below river level, they will probably yield fairly large quantities of water to wells. One of these deltaic patches is at the mouth of Canary Brook, the other larger patch at the mouth of Bogs Brook. Mr. E. Shurtleff, a local driller, reports that "good gravels" are present in the latter locality. Assuming that the aquifers will be recharged by the Connecticut River through the fine grained material occupying much of the flood plain area under heavy pumping conditions, 2 or 3 mgd might be obtained from each of the gravelly areas mentioned. If pumping wells must depend entirely on local recharge one-half mgd might be the maximum discharge that could be sustained. The same remarks will apply to the gravelly areas north of Stratford.

A small area southwest of Lancaster (Whitefield, N.H.-Vt., topographic sheet) appears to be underlain by coarse sediments and again, might yield water in quantity if recharged by the river through the intervening silty section.

Along the west bank of the Connecticut coarse sediments may be lacking except in a small deltaic areas around Brunswick Spring and at the mouth of Paul Stream (Guildhall, Vt.-N.H., topographic sheet). More than 1 mgd might easily be developed near the mouth of Paul Stream and several wells yielding one-half mgd or more might be developed from wells upstream if a deep gravel filled channel can be located. Ground-water storage should be good here relative to a one-half mgd discharge. The valley of Dennis Pond Brook, just north of Paul Stream may have similar characteristics. It is doubtful that as much as one-half mgd could be obtained in the gravelly reentrant north of Guildhall Station.

The Johns River that passes through Whitefield also lies in sub-basin L-1. No really good possibilities for developing ground water are apparent in the vicinity of Whitefield but test drilling may well demonstrate the presence of a favorable thickness of coarse sediments in the valley extending for 1 mile or so east of the village. A broad wash of gravelly sediments is present in the upstream area. Potential recharge is large relative to a possible ground-water development of up to 5 mgd and storage potential is good rather than otherwise. However, as noted above, specific information on the presence or absence of aquifers in the area discussed are lacking. The valley of Johns River downstream from Whitefield appears to be almost entirely filled with fines.

Sub-basin B

Sub-basin B covers the area drained by the Upper Ammonoosuc River which discharges into Connecticut River at Groveton, N.H.

The narrow valleys of the Upper Ammonoosuc and of North Branch above West Milan (Percy, N.H., topographic sheet) may not have either thickness or type of fill that will permit construction of high yield wells. Should it prove possible to develop up to 1/2 mgd here and there, there is every reason to believe that recharge potential is more than adequate for such a development in both valleys but storage capacity to supply water in dry periods is not the best that might be desired.

The terraced area adjacent to West Milan, N.H., on the south may be susceptible to a rather large ground-water development, 5 mgd or more, depending on the presence or absence of aquifers at moderate depth and the degree to which stream waters will infiltrate the ground when the ground-water levels are lowered.

Development of very large supplies of ground water on the low terrace along the Upper Ammonoosuc below West Milan will depend upon locating permeable aquifers susceptible to recharge from the river. It is believed that prolific aquifers are generally present and a few tens of million gallons a day might be developed in the more favorable areas (when located by test drilling) between West Milan and Groveton. A bridge test boring at Stark penetrated coarse sand and sandy gravel between 30 and 60 feet. The overlying material was also sandy. About 2 miles upstream from Groveton, Mr. E. Shurtleff reported that "clay and boulders" extended from the surface to a depth of 107 feet, below which 24 feet of pea gravel was penetrated. It is believed that the upper material reported is a mixture of clay deposited in an arm of the lake that extended part way up the river and coarse material that brought into the lake from upstream.

It is felt that not more than 1/2 mgd could be developed on high ground along Philips Brook north of the community of Crystal even if depth and type of fill should be found to be encouraging.

Sub-basin C

Sub-basin C lies in New Hampshire and includes the area drained by Israel River and its few very small tributaries. Lancaster is the only large center of population in the area.

As seen in surface exposures the upstream narrow valley of Israel River above Highlands (Mt. Washington topographic sheet) is underlain by gravels. According to Mr. E. Shurtleff these are highly permeable. The ground-water storage capabilities seem good and several wells yielding from 1/2 to 1 mgd might be located along the reach between Highlands and Randolph Station.

From Highlands downstream to Riverton, N.H. (Whitefield, N.H.-Vt. topographic sheet) the valley is broad but permeable beds here may be thin. As mentioned above, much of the late glacial flow from the upstream portion of the Israel River may not have discharged via the present lower valley. Recharge and storage potential are good here but the presence of deep aquifers is yet to be demonstrated.

Below Riverton and about 2 miles upstream from Lancaster test drilling has shown that gravels on the north bank of Israel River only extend to about 30 feet below the surface. However, pumping tests indicate that properly screened and developed wells in these gravels yield over 200 gpm per individual well. Considering the recharge potential from Israel River, it would seem then that up to 2 mgd might be developed from a battery of shallow wells between Riverton and Lancaster. However, the possibility of finding a deep channel in this reach, perhaps on the left bank of Israel River, from which higher yield wells might be developed should not be dismissed. Whether or not deltaic gravels are present at depth within the limits of the town itself cannot be determined from surface exposures.

Sub-basin L-2

Sub-basin L-2 includes the reach of the Connecticut River from Dalton downstream to East Barnet, Vt., at the mouth of the Passumpsic and southward to Woodsville, N.H. Gilman, Vt. is one of the few upstream villages in the area.

The upper reach of the Connecticut River includes the area of the Pattenville (Littleton?) Reservoir. Just above the reservoir, around Gilman, Vt (Whitefield, N.H.-Vt., topographic sheet), the valley fill appears to be coarse and it may be possible to develop ground water here in appreciable quantity from wells on both sides of the river. If conditions were found to be very favorable, the potential there would be limited only by the extent of infiltration of the river water. The short valley from East Concord to Gilman might yield up to 1/2 mgd from wells.

Below the Pattenville dam (Littleton, Vt.-N.H., topographic sheet) some coarse valley fill sediments are seen as far downstream as the mouth of Chandler Brook but no conclusion can be reached at this time regarding the position of the deep pre-glacial channel or the sediments therein. Coarse sediments are likely to be present at depth at the mouth of Chandler Brook (below West Waterford, Vt.).

The valley extending northward through West Waterford, Duck Pond and Stiles Pond was a late glacial spillway. This channel may be deep and it certainly is floored by coarse sediments. A half million gallons a day might be developed in this channel but above West Waterford School ground-water storage and recharge potential are poor.

The Connecticut River valley from East Barnet, Vt., to Woodsville, N.H. has an almost complete cover of silt and clay that effectively masks older permeable deposits, if any. The lowermost mile of Stevens River valley, west of the village of Barnet (St. Johnsbury, Vt.-N.H., topographic sheet), may be underlain by a deep channel filled with coarse sediment from which more than 1 mgd might be developed but test drilling would be necessary to confirm this possibility. At Kilfasset Farm, 1-1/2 miles above East Rygate, Vt. (Woodsville, Vt.-N.H., topographic sheet), bedrock is overlain by 105 feet of fine silt. Very small areas of coarse sediment may be present at the mouth of Manchester Brook just above East Rygate.

Test holes drilled at Monroe, N.H., opposite McIndoe Falls, Vt., penetrated silt and sharp gravel at 165 to 166 feet in one hole and, in large part, grey clay to 163 feet in a second hole. Whether deep lying aquifers are present here is yet to be determined by test drilling that is continued into bedrock.

At Woodsville the delta of the Lower Ammonoosuc should be productive of large quantities of ground water. At the Drive-in Theatre on the flood plain just south of Woodsville a well penetrated sandy and silty sediments to a depth of 60 feet and blue clay from 60 to 215 feet without reaching bedrock. If coarse sediments brought in by the Lower Ammonoosuc River are present at depth, they should be sought about 1 mile to the east-northeast of the location mentioned. Depending on the distribution of coarse beds at depth and degree of hydraulic connection with the river total ground-water potential in this delta area might range from few to many millions of gallons a day.

Sub-basin D

Sub-basin D is the area drained by the Passumpsic River of Vermont down to its point of discharge into the Connecticut River at East Barnet. Lyndonville and St. Johnsbury are the most important population centers in this area.

In the Passumpsic River system the valleys of the upper reaches of the tributary streams appear to be underlain by coarse gravels susceptible to development by wells. The valley of East Branch of the Passumpsic above Lyndonville, Vt., (Burke, Vt., topographic sheet) appears to be the more favorable of these tributary valleys. Probably over 1 mgd can be developed here in some limited areas and a total of perhaps over 5 mgd could be developed from several widely spaced wells located a mile or so above and below East Burke.

Eskers (elongate ridges formed beneath a stagnant glacier) along the valley floor of West Branch of the Passumpsic may be the best sites for wells if large developments are contemplated between Folsom and West Burke. Perhaps as much water could be developed here as along East Branch; storage capacities may be less favorable but the drainage area, and hence recharge potential, is greater.

Coarse gravels along Miller Run, about 2 miles above Lyndonville (Lyndonville, Vt., topographic sheet), may yield 2 or 3 mgd if they extend to moderate depth. Storage may be poor here but the recharge area is large.

The area around Lyndonville and immediately to the north is underlain by fines and the probability of encountering coarse gravels in any one place there cannot be determined from surface exposures. The town well at Lyndonville is said to have penetrated gravel from the surface to a depth of 40 feet. It yields 500 gpm (gallons a minute) with 19 feet of drawdown. The coarse sediments present in the Lyndonville area may be stringer-like deposits oriented in a north and south direction.

Between Lyndonville and St. Johnsbury (St. Johnsbury, Vt.-N.H., topographic sheet) coarse gravels are present along the east bank of Passumpsic

River. Below St. Johnsbury gravels generally flank the river to a point more than a mile below the village of Passumpsic. Further, the lower valley of Sleepers River that empties into the Passumpsic just below St. Johnsbury may be underlain by productive gravels. Supplies reckoned in terms of a few millions of gallons a day should be available here from place to place. The total yield that might be developed between Lyndonville and Passumpsic, Vt., would depend on the number of wells that might be drilled in the gravelly strata without great mutual interference and which are susceptible to recharge from the river.

The town well at St. Johnsbury is reported to yield 1.2 mgd (million gallons a day) with 1 foot of drawdown. Assuming that this represents an order magnitude correctly, it is evident that the formation there is very permeable and infiltration from the river occurs very quickly.

Along Moose River, from the Passumpsic at St. Johnsbury and as far upstream as Concord (Littleton, Vt.-N.H. topographic sheet) gravelly fill appears to be present. Ground-water storage is moderate. Wells yielding more than one-half mgd each might be sited downstream from Concord and on the south side of Moose River below East St. Johnsbury. There Moose River would furnish ample recharge to such permeable beds as are present but upstream from Concord, it seems unlikely that high yields can be obtained from wells.

Summarizing, ground water should be available in moderately large quantities along both East and West Branches of Passumpsic River. Eskers may mark the better well sites. The lower few miles of Millers Run valley is less promising. Wells located in coarse sediments along the east bank of the Connecticut River from Lyndonville to St. Johnsbury may develop high yields. Prospects appear to be poor along Moose River.

Sub-basin E

Sub-basin E occupies a large segment of the upper Connecticut valley in New Hampshire and is the area drained by the Lower Ammonoosuc and Wild Ammonoosuc Rivers. Littleton, Lisbon, Bath and Franconia are some of the better known cities and villages in the area.

The Lower Ammonoosuc River system extends as far east as Crawford Notch and the base of Mt. Washington. In this headwater area along Crawford Brook, from below Fabyan, N.H., (Mt. Washington topographic sheet) and for several miles southeastward toward Crawford Notch (Crawford Notch topographic sheet), there is an apparently thick sand and gravel accumulation from which supplies of 1/2 mgd per well may be available. Ground-water storage appears to be large and perhaps as much as 2 mgd sustained yield might be developed in the area.

There may be excellent possibilities of developing ground water in quantity in the Twin Mountain, N.H., area (Whitefield, N.H.-Vt., topographic sheet). Immediately downstream on both sides of the Ammonoosuc River coarse gravel appears to be widespread and may lie deep in some places. Presumably gravels brought down through the glacial spillway north of Twin Mountain accumulated in this area and even though the north bank is masked with fines, that area may be favorable also. The flow of the Lower Ammonoosuc here is large and over 10 mgd might be developed if coarse sediments susceptible to recharge by the river are found at moderate depth.

Between Pierce Bridge and southward to Gale River Campground (Franconia, N.H., topographic sheet) is a wide flat gravel floored valley through which drainage from the Lower Ammonoosuc once passed southward to Gale River. It seems likely that 1 mgd or more might be developed in the vicinity of Gale River Campground where recharge conditions are good. However, any development here, as elsewhere, will depend on locating deeper channels filled with a good thickness of saturated alluvium.

From Pierce Bridge (Whitefield, N.H.-Vt., topographic sheet) to the vicinity of Littleton (Littleton, Vt.-N.H., topographic sheet) only fines are exposed along the Lower Ammonoosuc River. Gravelly sediments may be present along the tributary valley that extends north from Wing Road but recharge there is poor.

From Littleton to the mouth of the Lower Ammonoosuc at Woodsville, N.H., coarser sediments are commonly seen in gravel and sand pits. Bedrock is exposed here and there in the river and suggests that a deeper pre-glacial channel filled with alluvium may not be present. However, one town well at Littleton penetrated 140 feet of loose to tightly packed till, indicating that a deep pre-glacial channel is present there. The well was finished with no. 120-slot screen at 38 to 54 feet and yielded 204 gpm with $17\frac{1}{2}$ feet of drawdown. If deep lying permeable beds are found downstream to Woodsville, the amount of water that could be developed by wells might be very large.

The middle reach of Gale River around Franconia and for a mile or more up Meadow Brook (Franconia, N.H., topographic sheet) and for 2 or 3 miles up Ham Branch (Moosilauke topographic sheet) are fairly promising areas for development of, say, up to 1 mgd in Mill Brook and more than 1 mgd in Ham Branch. This area was also a glacial spillway and gravels may be relatively thick at the lower elevations. Downstream a small area about two miles northwest of Franconia may also offer good prospects; gravels may be sufficiently thick to permit development of wells and, although storage is not particularly great, recharge from Gale River should be optimum.

The valley that passes through Patridge Pond, Dodge Pond and Ogontz Lake (Littleton topographic sheet) and opens out into the Lower Ammonoosuc near Salmon Hole School may be susceptible to development of ground water in small quantities. This glacial spillway appears to be gravel choked and the thickness of the gravel is probably much more than a thin wash. A well developed between Ogontz Lake and Dodge Pond, for instance would have surface storage in the stream to draw upon as well as appreciable underground storage. Perhaps a firm yield of 1/2 mgd could be developed.

At Babbit Hill below Lisbon, it is possible that the pre-glacial channel of the Lower Ammonoosuc passed east of that hill rather than in its present course. However, there is no field evidence to support this suggestion.

Bedrock is exposed in places along the broad part of the wide channel of the Wild Ammonoosuc from Swiftwater to its junction with the Lower Ammonoosuc (Moosilauke topographic sheet). It seems unlikely that any large quantity of ground water could be developed there. Above Swiftwater gravelly deposits in the Wild Ammonoosuc valley are sparingly present and prospects are poor.

Summarizing, moderate supplies of ground water are available along the uppermost reach of the Lower Ammonoosuc and large supplies may be available along that river from Twin Mountain to Pierce Bridge. Below Pierce Bridge the possibility of developing large quantities of ground water is questionable but it seems more likely that large supplies might be developed along the lowermost reaches of the river.

Moderate supplies of ground water should be available along lower Ham Branch and Meadow Brook in the Gale River headwater area.

Ground-water potential along the Wild Ammonoosuc seems poor.

Sub-basin F

Sub-basin F is in Vermont and covers the area drained by Wells River above the mouth of that river and its few short tributaries. South Rygate and Groton are the largest communities in the area.

About 1-1/2 miles upstream from Wells River, a recently opened pit exposes coarse gravels lying on bedrock at river level (Woodsville, Vt.-N.H. topographic sheet). It is likely that a deep channel is present along the river valley in which similarly coarse sediments are present from which yields up to 1 mgd might be developed from properly constructed wells. Farther upstream, two miles below South Rygate, large faces of pebbly fine sand were exposed during road construction; it is thought that these sediments may become coarser with depth. In test drilling at White Brothers milk processing plant at South Rygate, the R.E. Chapman Co., drillers, reports that unconsolidated sediments extend to more than 69 feet below the surface. "Medium sand and scattered gravel" was penetrated between 45 and 56 feet below the surface. Obviously a high yield well could be constructed here. Mr. Johnson of Montpelier reports that a good gravel aquifer is present at

80 feet near the center of town. Above South Rygate coarse sediments are exposed from place to place as far as North Branch.

Summarizing, it may be possible to develop a number of fairly large yield wells in Wells River valley as far upstream as Groton, Vt. In this reach perhaps 5 to 10 mgd might be developed without difficulty but above South Rygate field inspection suggests that alluvial fill may be thinner and development of large supplies would be more difficult.

Sub-basin L-3A

Area L-3A comprises the reach along the Connecticut that extends from the town of Wells River, Vt., and southward through Haverhill, N.H. Woodsville, N. H., opposite Wells River, is not included.

A very large delta is present at North Haverhill, N.H. (Woodsville, Vt.-N.H., topographic sheet). These sediments were deposited when much or part of the Lower Ammonoosuc River drainage emptied into the Connecticut through the pass that extends from Swiftwater southwestward through Center Haverhill (Moosilaukee, N.H., topographic sheet). As at Woodsville, only somewhat fine or medium sand is seen near the Connecticut but coarse beds are exposed in pits near Center Haverhill and it is expected that permeable sands and gravels would be encountered at depth a half mile or so east of Route 5, that is just east of North Haverhill village. Ground-water storage here is large but recharge in the area is limited and perhaps about 1 mgd discharge is all that could be sustained.

Sandy clay was penetrated to a depth of 90 feet along Route 5 at North Haverhill but about 1-1/2 miles north of the village gravel underlying thick clay is reported between 61 and 76 feet.

At the town of Wells River on the Vermont side of the main stem, just south of the mouth of Wells River, a well 160 feet deep, said to be developed in gravel, yields 360 gpm. Presumably the gravelly beds from which water is drawn is recharged by infiltration from the Connecticut as well as Wells River. Surface exposures do not indicate that the well site offers any particular promise in that it is near the rock wall of the valley on a low silty terrace. If permeable gravels extend for some distance downstream, the amount of water that could be developed by wells would depend largely on how close wells might be located to one another and the ease of infiltration of water from the river. A development of several million gallons a day, at least, seems possible.

Sub-basin L-3B

Sub-basin L-3B includes a narrow area in Vermont that extends from Haverhill on the Connecticut northwestward to the limit of the basin and a somewhat narrow section southward along the Connecticut from Haverhill to White River Junction. The lowermost reaches of Ompompanoosuc, West and White Rivers in Vermont, and several small tributaries on the New Hampshire side of the river lie within the sub-basin. Haverhill, Piermont, Lyme and Hanover, N.H., and Norwich, and White River Junction, Vt. lie within the area.

At the drive-in theatre at Fairlee, Vt., (Mt. Cube, N.H.-Vt., topographi sheet) gravels are reported near the bottom of a 91-foot well. At East Thetford railroad station, gravel was penetrated beneath clay at 130 feet. However, along the whole reach from Bradford to Pompanoosuc on the Vermont bank of the river, only fines are exposed and the occurrence of sporadically distributed gravels at depth cannot be predicted.

Coarse kame gravels are present at the junction of the Ompompanoosuc with the Connecticut and extend for about 2 miles downstream. At the Farrel Farm, on Route 5 three miles north of Norwich (Hanover, Vt.-N.H., topographic sheet) 125 gpm with 16 inches of drawdown was obtained from gravel at 63 feet in a recently completed 8-inch well, according to O. Thyng, driller. The well was equipped with 15 feet of no. 60-slot screen. It seems likely that deep aquifers here would be recharged by the river. Hence, from Pompanoosuc, Vt., to Norwich it may be possible to develop 1 mgd or more each from several wells sited along that 2-mile reach.

The area around Norwich and Lewiston may have some ground-water potential. However, test drilling in that area appears to show that the alluvium is thin.

The lowermost reach of White River appears to be unfavorable for ground-water developments unless it should be found that a deep channel exists there. Rock is exposed in the streambed in many places and borings made where Route 91 crosses White River, just above White River Junction, show that bedrock lies about 30 feet below normal high water on both sides of the river. However, a municipal well yielding 250 gpm has been developed in the shallow sediments above bedrock at Hartford, Vt., across the river from White River Junction. Bedrock was encountered at about 60 feet below river level in a domestic well located 2 blocks west of the Connecticut.

White River Junction area itself appears to offer small prospect of developing ground water in quantity unless it be found that gravels along the Connecticut River extend below river level. West of the railroad bedrock is probably shallow but on the low terrace east of the railroad south of the town it is possible that sediments are part of the Mascoma River delta. In any event coarse sediments are exposed in that narrow strip and it may be possible to develop 2 or 3 mgd in that area.

On the New Hampshire side of the Connecticut River, ground water may be available only in small quantities at Haverhill, N.H., (Woodsville, Vt.-N.H., topographic sheet). Possibilities may be slightly better at Piermont (Mt. Cube, N.H.-Vt., topographic sheet) along Highway 10 and above that highway along lower Indian Brook.

At Orford, N.H., a delta is developed along the lower course of Jacobs Brook, less than a mile southeast of the village. However, here probably not more than 1/2 mgd could be developed unless conditions should prove to be especially favorable.

The village of Lyme, N.H., lies on a delta. If these beds extend well below water level there may be a moderate storage area to draw upon and up to 1 mgd might be developed from wells immediately southwest of the village. Bedrock lies at 95 feet below the surface in the village but the character of the material above bedrock is not known.

Only fines were mapped along the Connecticut from Lyme to West Lebanon, N.H. (Hanover, Vt.-N.H., topographic sheet).

About 4½ miles above Hanover, below Pinneo School, only fine sand was encountered down to bedrock at 130 feet. At the U.S. Army Cold Regions Research Laboratory a mile and a half north of Hanover, medium sand was penetrated in one well at 120 to 130 feet and at 165 to 170 feet. Silt extended to 202 feet. In a second well medium sand was found at 135 to 145 feet and sand and gravel from 145 to 150 feet. The well yielded 322 gpm with 4 feet of drawdown. The distribution of aquifers here, as elsewhere, is sporadic and the development of strong aquifers recharged from the river will depend upon locating potential aquifers by test drilling, preferably to bedrock.

Summarizing, in most places along the Connecticut River from Haverhill to White River Junction, ground water prospects depend on locating chance lenses of coarse sand or gravel beneath a thick cover of fine sediments. Coarse sediments are present in the lower Ompompanoosuc valley and downstream along the west bank of Connecticut River to Norwich; moderate to large supplies may be available in those areas. Along the east bank of the Connecticut the delta at Lyme may be a somewhat favorable area. The lower White River valley does not appear to be underlain by a deep pre-glacial channel and prospects for even moderate ground water supplies there seem generally poor.

Sub-basin G

Sub-basin G is Waits River drainage area in Vermont. The town of Bradford, Vt., is located in this sub basin on the Connecticut.

The lower reach of Waits River valley is gravel filled, according to the record of the Bradford town well. Waits River turns sharply northward from its old channel south of the city and empties through a rock gorge. However, at the town well site gravels were encountered to a depth of 72 feet and, further, data at hand do not show that bedrock was reached there. It is altogether likely that an old gravel-filled channel extends for some miles upstream in which several wells might be developed having capacities up to 1 mgd.

The well at Bradford, which yields 700 gpm with 26 feet of drawdown, ends at about 60 feet below the level of Waits River and about 30 feet above the level of the Connecticut. Recharge from Waits River, therefore, can be effective but not from the Connecticut. To develop the maximum amount of water in this locality it would be necessary to draw from such deeper gravels as may be present.

Whether the gravels encountered in the Bradford well extend farther riverwards and underlie the fine terrace sands flanking the river and extend under cover of fines down river from Bradford can only be determined by test drilling.

Sub-basin H

Area H includes the Ompompanoosuc River in Vermont beginning about 4 miles above its mouth and its West Branch above Union Village dam.

Both the Ompompanoosuc and West Branch lie in fairly narrow valleys which appear to be floored by coarse sediments. On West Branch as much as a total of 2 or 3 mgd might be developed from several wells in the wider valley area above South Strafford, Vt. In the valley head north of Strafford perhaps 1/2 mgd might be developed. Below South Strafford permeable gravels are reported at a depth of 70 feet at Copper Flat. Presumably gravels are present generally in the narrow valley bottom to the junction with the main branch of the Ompompanoosuc.

Along the main stem of the Ompompanoosuc bedrock lies as deep as 80 feet in Thetford Center, Vt. However, scant data at hand do not show anything of the distribution of coarse sediments at depth in the well defined channel that extends as far north as West Fairlee although surface exposures suggest that they should be present. More than 3 mgd might be developed in this valley if coarse sorted sediments are present at moderate depth.

Sub-basin I

Sub-basin I includes the White River drainage system upstream of a point 6 miles above White River Junction, that is, from just below West Hartford, Vt

Speaking generally, the river valleys in this system are commonly somewhat narrow but are underlain by lenses of permeable sediments from which well water supplies can be developed in worthwhile quantities in many places. Below South Royalton bedrock is present in the riverbed in many places and ground-water potential is thought to be small. Along First Branch rock also appears in the riverbed at Tunbridge and upstream and in that reach only small supplies may be available unless a deep sediment filled channel is present.

At Roahester along the upper part of White River itself, a screened well 45 feet deep develops 100 gpm with 4 feet of drawdown. On Tweed River tributary to White River a 60-foot well is said to have had a flow of 300 gpm when it was completed. When visited by the writer (October, 1964) the estimated flow at about 10 feet above river level was about 100 gpm.

At Bethel, Vt., where Third Branch joins White River, 150 gpm with 9 inches of drawdown was developed from a 69-foot screened well, according to O. Thyng, driller. At Randolph, upstream on Third Branch, fines are present at the surface in many places and test drilling to bedrock will be necessary to establish the presence of coarse beds. The more productive of two municipal wells is 188 feet deep and originally yielded 400 gpm, according to data furnished by Layne-New England Co. It is equipped with 8 feet of no. 200-slot screen.

Therefore, aquifers may be assumed to be generally present in the well developed valleys of Tweed River, Third Branch and Second Branch, in the lower part of First Branch and in upper reaches of White River itself. Yields in those areas may be reckoned as a function of ease of infiltration of the streamflow but offhand it appears that 5 mgd or more might be developed from properly located and constructed wells along each of the larger areas mentioned, over 2 mgd along Tweed River and up to 1 mgd along lower part of First Branch.

Sub-basin J

Sub-basin J includes the Mascoma River drainage area which lies entirely in New Hampshire. The city of Lebanon is the largest center of population and West Lebanon, Enfield, and Canaan are relatively large villages.

Broad rather flat valleys characterize the drainage courses west of Mascoma Lake, N.H., (Mascoma, N.H. - Vt., topographic sheet). These may be underlain by till and covered with a relatively thin wash of gravelly beds from which only a little ground water can be developed. More information is needed before this area can be properly evaluated. However, some areas along upper Mascoma River and lower parts of Goose Pond Brook and Indian River may be underlain by favorable thicknesses of permeable sediments and offer opportunity for developing ground water in quantity. The West Canaan, N.H., area, for instance should provide excellent ground-water storage if the sediments are present in reasonable thicknesses. Perhaps not more than 2 or 3 mgd should be considered as the ground-water capability of this area until more information is at hand.

Esker-like forms along the Little Brook glacial spillway south of George Pond may be the better sites for developing up to 1/2 mgd of ground water.

Up to 5 mgd water should be available from the Great Hollow valley immediately north of the Mascoma River above Lebanon, and along Mascoma River itself above Lebanon if sandy gravel or gravel extends to a depth of 50 feet or more in that area. Recharge from the Mascoma River would be absolutely necessary to sustain such a development. The presence of a deep preglacial channel is suggested by the fact that a well at the village of Mascoma penetrated 163 feet of unconsolidated sediments without reaching bedrock.

The wide valley area west of Lebanon may be similarly characterized.

The Mascoma River delta on the Connecticut at West Lebanon, N.H., (Hanover, N.H.-Vt., topographic sheet) should be productive of enormous quantities of ground water if the widespread coarse gravels so well exposed in that area extend well below the level of the Connecticut River and make possible recharge from that river. One mile south of the mouth of Mascoma River and two-tenths of a mile east of the Connecticut highly permeable gravels were penetrated between 50 and 78 feet. The highly favorable delta area extends along the east bank of the Connecticut for almost 3 miles south of West Lebanon (in part in sub-basin L-4). A minimum of 5 mgd should be available here with ease unless conditions are almost exactly opposite from what is suggested by surface exposures.

Sub-basin L-4

Area L-4 includes an irregular area covering the valley of Connecticut River and minor tributaries from below the Mascoma River delta to Bellows Falls. The drainage areas of the Sugar River of New Hampshire and the Ottauquechee, Black, and Williams Rivers of Vermont are excluded.

Between Hartland, Vt., and Hartland Four Corners coarse sediments along Lulls Brook may permit development of 1/2 mgd or more. Fine gravel and coarse sand was penetrated in a well in the latter community between 112 and 139 feet. Near the Hartland railroad station, near the Connecticut River, the section was largely silt that graded to sand at 142 feet, according to Mr. D. Herrick, a local driller.

Across the river at the mouth (delta?) of Blow-Me-Down Brook coarse sediments are seen in surface exposures but it cannot be determined by data at hand whether this area is very favorable for ground-water developments or only somewhat so.

Three wells have been developed at Windsor, Vt., (Claremont, Vt.-N.H., topographic sheet); one, 78 feet deep yields 1,250 gpm with $11\frac{1}{2}$ feet of drawdown. A second well 90 feet deep yields 1,260 gpm with $30\frac{1}{2}$ feet of drawdown and a third well 90 feet deep yields 1,140 gpm. The section is all gravelly in the first well mentioned but in the second well the section is silty to 52 feet and becomes coarse with increasing depth. The third well encountered clay and fine sand to a depth of 30 feet and gravels below. However, daily discharge is believed to average less than 400 gpm. Inasmuch as the wells extend to more than 30 feet below river level here, it is evident that a very large discharge of ground water might be maintained if infiltration from the Connecticut were induced, either directly through relatively coarse sediments or indirectly through a silty riverbed. Where further development of ground water is contemplated, the area on the west side of Route 5 north of Lake Runnemede should be explored.

The narrow valley of Mill Brook north of Mt. Ascutney offers little likelihood of furnishing much ground water. Coarse sediments might be sought at depth in the old Mill Brook valley south of Horseback Ridge. Above Brownsville, Vt., 5 miles west of Windsor, two broad areas have functioned as gravel traps and accumulations of sediment there furnish modest storage capacity. Two wells developed in shallow gravels at the Eastern Manganese Talc Company plant north of Felchville have a combined yield of 250 gpm. Whether the combination of storage area and recharge is sufficient to maintain such a sustained yield is problematical but the data do indicate that the gravels are permeable and that inexpensive screened wells of small diameter can easily supply modest industrial requirements in many localities distant from large streams. The area below Rush Meadow School is wider and longer than the area north of Felchville and, in its downstream portion, should yield 1/2 to 1 mgd without difficulty.

Returning to the Connecticut River, gravels are very sporadically developed north of the village of Ascutney. However, there is at least the possibility that gravels at the mouth of Mill Brook reach the river under a cover of fines and make possible the development of 1/2 mgd or more of ground water.

Down river, at the village of Weathersfield Bow, according to Mr. Dean Herrick, gravels were encountered at 112 feet below silty beds but a mile south of the village only clay was penetrated to a depth of 325 feet, that is, at about 255 below the level of the Connecticut River. On the terrace 2 miles north of the mouth of Black River, a domestic well along the Connecticut was completed in a "sandy streak" beneath silt (?) at 165 feet. However, a deep well at the Liquidometer Company, 2 miles north of Bellows Falls, is said to yield a million gallons a day.

On the New Hampshire side of the river (Claremont, N.H.-Vt., topographic sheet), a well drilled along Route 12, 1/2 mile below Cornish Bridge to Windsor, encountered 295 feet of clay and was abandoned.

At North Charlestown, N.H., coarse deltaic sediments are exposed rather high above the level of the Connecticut where the Little Sugar cuts across the terrace flanking the main stem. These beds interfinger with fine lake (lacustrine) sediments. However, it appears that coarse beds might extend below river level in this area and offer possibilities of ground-water development.

Coarse sediments are present also just to the south along lower Beaver Brook but whether or not 1/2 mgd might be developed here must be determined by test drilling. A small area of coarse sediments between Oak Hill and the Connecticut, north of Charlestown also seems worthy of exploration.

Summarizing, prospects for developing large supplies of ground water along the Connecticut River from North Hartland to Bellows Falls are generally poor. Silt and clay extends to considerable depth, more than 300 feet in one place, and the distribution and character of possible aquifers beneath the silt and clay is known in very few places. At Windsor, large ground water supplies have been developed in the delta of Mill River. A high yield well has been developed below the mouth of Williams River, perhaps in coarse sediments brought down by that river. On the New Hampshire side of the Connecticut River deltaic deposits at the mouth of Blow-Me-Down Brook downstream from Hartland and near the mouth of Little Sugar River above North Charlestown may have good ground water potential.

Small gravelly areas upstream in Mill River will sustain only modest perennial yields.

Sub-basin K

Sub-basin K includes the drainage area of the Ottauqueechee River, entirely within Vermont. It joins the Connecticut at North Hartland. Woodstock, Vt., is the largest community in the area.

The essentially north-south section of the Ottauqueechee above West Bridgewater (Rutland topographic sheet) is a pre-glacial channel developed along a zone of structural weakness. The fill of gravelly sediments in this channel probably varies greatly in thickness and it is believed that large supplies of ground water cannot be obtained there. Gravel extends only to a depth of 40 feet or so at West Bridgewater, Vt., (Woodstock topographic sheet) and bridge borings show that a 25-foot thickness of gravel is present in the very narrow canyon between West Bridgewater and Bridgewater Corners. Perhaps 1/2 mgd might be obtained from each of two or three wells in that lower reach.

A well at Bridgewater Corners encountered 45 feet of gravel and at Bridgewater, a short distance downstream, gravel extends to 90 feet below the low flood plain. On the flat plain just north of the village of Woodstock silt and clay extends to more than 100 feet below the surface. However, on the south bank of the river Mr. Moyer, a local driller, developed 150 gpm from an open end well ending in gravel at about 50 feet below the level of the river. At the Texaco garage a mile north of town 75 gpm was developed from a 97-foot open end well in gravel. The municipality has a 248-foot well ending in rock that yields 23 gpm.

It is thought that between Woodstock and Bridgewater over 5 mgd might be developed from wells which penetrate the maximum thickness of sediments present beneath the silt and clay cover if these sediments are recharged by the river. Test drilling may be necessary to locate the optimum locations for wells.

At Woodstock itself silty sediments have been encountered in test drilling that was not continued to bedrock but, as noted above, gravels have been encountered elsewhere and screened wells might be expected to yield more than 1/2 mgd in some locations.

Downstream little is known of ground-water possibilities. Mr. Moyer states that near Taftsville, Vt., (Hanover, Vt.-N.H., topographic sheet) permeable gravel is encountered in some places beneath clay at 115 feet. Below Queechee only fine sediments are exposed at the surface and it is not known whether gravel is present below the silty cover.

At North Hartland a gravel-pack well developed in shallow gravel yields 140 gpm with 7 feet of drawdown.

Sub-basin M

Area M is the Sugar River drainage system in New Hampshire in which Claremont and Newport and Lake Sunapee are located.

The generally broad valley of South Branch extending south from Newport, N.H., (Sunapee topographic sheet) was a glacial spillway and is floored by gravelly sediments that should provide excellent storage capabilities. At the Newport Dairy 10 feet of water-bearing gravel was penetrated between 80 and 90 feet in an 8-inch diameter well. This well, equipped with 5 feet of no. 80-slot screen, yields 100 gpm with 21 feet of drawdown. Up to 5 mgd of water a day might be developed in the 4 mile reach south of Newport if deep permeable sediments are widely distributed. The underground storage potential here is excellent.

North of Newport the reach from Newport to Croydon Flat may also be very favorable. In both these areas underflow may be important and more water available for continuous recharge than is evident from the streams. An additional 4 or 5 mgd may be available in this northerly area.

Smaller quantities may be available from the broad valley of North Branch above Croydon, N.H.

Possibly not more than 1 mgd would be available in the area around Guild and Wendell, east of Newport.

At North Newport and on either side of Sugar River at Kellyville, N.H., appreciably large quantities of ground water would be available only if the patches of sediments there extend a few tens of feet below river level. It is thought that they may not do so.

Gravelly beds are present on the south bank of Sugar River 2 miles east of Claremont (Claremont, N.H., topographic sheet). A municipal well there penetrated gravelly sands between 83 and 97 feet and between 135 and 160 feet. This well is equipped with 8 feet of no. 60-slot screen and yields 350 gpm with 110 feet of drawdown. As much as 1 mgd might be obtained here if the well were fully screened. The aquifers appear to be recharged from Sugar River. From 5 to 10 mgd might be developed here if thick permeable beds fairly near the river can be located by test drilling.

Coarse gravels 80 feet above the level of the Connecticut River are present in the valley northwest of Twistback Hill, Claremont. These gravels mark the course of the Connecticut River in glacial and perhaps also pre-glacial times. If sediments of the type exposed extend to below river level they should receive copious recharge from both the Sugar and Connecticut Rivers.

Sub-basin N

Sub-basin N includes the drainage of the Black River system in Vermont to its junction with the Connecticut. Ludlow, Proctorsville and North Springfield and Springfield are the largest centers of population.

The northernmost reach of this system lies in a north-south canyon extending more than 7 miles north from Grahamville, Vt., (Ludlow, Vt. topographic sheet) in which several lakes are present. This canyon was a pre-glacial stream valley and functioned as a glacial spillway and is underlain by thick gravelly beds. However, Mr. F. Moyer reports that gravels are 50 to

60 feet thick (extending to more than 30 feet below river level?) at Plymouth Union, 3 miles north of Grahamville. At the north end of the small lake north of Echo Lake a 130-foot well ends in gravel. At the south end of Rescue Lake thick coarse gravels lie upon bedrock at 139 feet.

At Grahamville a loss of stream velocity occurred at the widening of the canyon there and the sediments are deltaic. The valley from Grahamville south to Ludlow and thence east to Proctorsville and Cavendish, Vt., is choked with sediments of glacial origin. Beyond this point glacial streams spilled southward through Proctorsville and Duttonsville Gulfs and, still later, found easier outlet beyond this point through the narrow rock walled canyon which is the present course of the Black River. In the gravelly valley from Grahamville to Ludlow it is likely that several wells yielding 1/2 mgd or more each might be constructed. Scant data in the Proctorsville area suggest that much of the sediment there is fine grained and development of large supplies of ground water may be difficult.

The valleys extending northward from North Springfield, Vt., through Perkinsville and Downers to Felchville, Vt., were also glacial spillways and received sediment from the north for a time. The North Springfield area also probably received some sediment from the west via the valley extending to Gassetts and, at a later stage, from the present Black River canyon at Downers. According to Carlson and Lundin, drillers, in this gravelly area depth to bedrock is greater than 100 feet 1/2 mile southwest of Downers, at which depth permeable gravel was penetrated. A well on the south side of Route 10 a half mile west of the center of the village of North Springfield was completed in gravel at 100 feet but in another well immediately to the north bedrock was reached at 60 feet. Storage potential is good along North Branch of Black River and good yields from wells, perhaps up to 1/2 mgd should be available in the broad valley above Amsden and from Downers to North Springfield. More to the east, in the valley south of Nelsons Corner (Claremont, N.H.-Vt., topographic sheet), smaller yields should be available.

A dam is being constructed just above North Springfield, Vt. However, North Springfield is presently pumping ground water from alluvial beds immediately adjacent to the Black River below the dam. One group of 30 small-diameter wells provides almost 1 mgd. A second group of four wells range from 33 to 52 feet in depth and yield, respectively, 100, 100, 200, and 300 gpm. They discharge about 2/3 mgd.

Black River lies largely in a rock cut channel from the upstream limits of Springfield to the Connecticut and the opportunities of developing ground water in that reach is very poor.

Sub-basin O

Sub-basin O lies in Vermont and comprises all of the Williams River drainage system to the mouth of that river on the Connecticut. The town of Chester is the only center of population of any appreciable size in this basin.

The Williams River received drainage from the Black River system to the north in glacial times via the Proctorsville and Duttonsville Gulfs (Ludlow, Vt. topographic sheet). As a result the volume of gravels present around Gassetts, Vt. and in most of the valley southward to and just beyond Chester is greater than might otherwise be expected. The town of Chester is supplied from a 47-foot deep gravel well that yields 50 gpm with 6 feet of drawdown. It seems likely that several wells of 1/2 mgd capacity or more might be developed on low ground around Chester and in the first two miles of valley north of the town.

Storage capacity of sediments along Middle Branch west of Chester is not as great but useful volumes of ground water could undoubtedly be developed there also. At Reedville gravel lies upon bedrock at a depth of 80 feet. Perhaps 1 to 2 mgd sustained yield might be developed here whereas up to 3 mgd seem likely from development of the valley north of Chester.

The valley of Williams River below Chester may be favorable for ground-water developments. Gravelly areas are present along the river banks above Rockingham and are present under a cover of fine-grained sediments near the mouth of the river. If a buried valley extends several tens of feet or more below river level several millions of gallons a day of ground water may be developed here with ease.

Sub-basin P

Sub-basin P covers the Saxtons River drainage area of Vermont. The village of Saxtons River is the only large settlement in the area. (Bellows Falls, at the mouth of Saxtons River, lies in Area L-5.)

Carlson and Lundin, drillers, report that in the community of Saxtons River (Saxtons River, Vt., topographic sheet) an 80-foot well penetrated only gravel. Between Saxtons River and Cambridgeport, Vt., the valley is very narrow and has an unpromising aspect--yet Mr. Moyer reports that a 60-foot thickness of gravel is present along the south bank of the river about midway between the villages mentioned. Bull Creek valley is fairly wide for about 2 miles south of Cambridgeport and appears to offer good storage potential. Up to 1 mgd might be developed there. The valley south of Grafton has less alluvium but may offer some possibility for ground-water development. Elsewhere the valley of Saxtons River and its tributaries are quite narrow.

The potential yield of wells along upper Saxtons River is problematical. Below the town of Saxtons River only fine sediments are exposed.

Sub-basin Q

Sub-basin Q includes the drainage area of Cold River and its tributaries. Cold River, which lies entirely in New Hampshire, empties into the Connecticut River opposite Bellows Falls, Vt. The village of Alstead is the only center of population in the area.

A very large gravel filled area is present at the mouth of Cold River (Bellows Falls, N.H.-Vt., topographic sheet). Much of this gravel may well have originated with blocking of the Connecticut downstream at Bellows Falls by glacial ice, at which time drainage of the main stem passed eastward through the gap below South Charlestown and down into the lower Cold River system. Old data at hand show that in the Walpole-Cold River-Drewsville area the surficial gravels bottom out upon clay or silt at 15 to 30 feet. However, test drilling was not continued on to bedrock and what might be present below the clay or silt was not established. In 1966, however, a well located on the low terrace north of Walpole encountered 24 feet of fine to coarse sand, 16 feet of clay and, from 40 to 70 feet, 30 feet of coarse sand and gravel. According to data supplied by the Layne-New England Company the well is equipped with 15 feet of no. 100-slot screen and yields 305 gpm with $2\frac{1}{2}$ feet of drawdown. Recharge from the Connecticut River is likely. In the gravel fill area of Cold River and for a mile up Great Brook test drilling to bedrock may prove the presence of other aquifers (as at Claremont) capable of yielding 1/2 mgd or more. There may also be ample opportunity for developing wells of 1/2 mgd capacity or more in the valley bottom upriver between Alstead, N. H. and South Acworth; the terrace area southwest of Beryl Mountain seems especially favorable. A total sustained yield of 3 or 4 mgd in this area is a conservative estimate of the ground-water potential here.

Sub-basin L-5

Sub-basin L-5 includes that area along both sides of the Connecticut River from Bellows Falls through Brattleboro to Vernon. The drainage area of West River which empties into the Connecticut above Brattleboro is excluded however.

Only fines have been noted in and around Bellows Falls, Vt. (Bellows Falls, Vt.-N.H., topographic sheet) and unless test drilling should show the presence of gravels at depth, say, north of Bald Hill at Westminster, the area must be considered nonproductive of ground-water supplies.

Deltaic sediments are present high on the slopes west of Westminster Station but nearer the Connecticut a thick section of clay or silt is encountered. According to the Green Mountain Artesian Well Co., on the terrace just north of Westminster Station (elevation 320 feet) silty clay was penetrated to a depth of 373 feet, at which depth a coarse sand or gravel was found. At Westminster Station (elevation 249 feet) a 3-foot gravel stratum was encountered at 240 feet in another domestic well. The gravel is said to be highly permeable.

Downstream at the village of Putney (Brattleboro, Vt.-N.H., topographic sheet) it should be possible to develop up to 1 mgd from wells sited along Sacketts Brook upstream from the center of the village. At the village (elevation about 400 feet) a domestic well 134 feet deep penetrated "good" gravels. Gravel is also reported just south of Dutton Pines State Forest Park. Whether or not coarse sediments extend well below the water table in this area making possible high yields sustained by infiltration from the Connecticut River is not known.

Test drilling in the gravel pits a mile south of Brattleboro demonstrated the presence of prolific aquifers but the water is said to have had an undesirable iron or manganese content. It is not known whether the test wells were pumped at a high enough capacity to induce strong recharge from the Connecticut River. Unless this were done, the water discharged would reflect the character of the saturated gravel mass and local recharge rather than the quality of water that would be discharged when high capacity production wells were put in service.

Still farther downstream on the Vermont side of the river kame gravels are present between North Vernon and Vernon. According to data furnished by the Green Mountain Artesian Well Company, an open end well in gravel produced 60 gpm at a depth of 134 feet just west of Vernon. Unless wells here were to lower the water table to the extent of inducing recharge from the Connecticut, probably not more than a total 1/2 mgd sustained yield could be developed from two or three wells. However, if recharge from the Connecticut can be counted upon, probably 2 mgd sustained yield could be developed.

On the New Hampshire side of Connecticut River below Walpole (Bellows Falls, N.H.-Vt., topographic sheet) that is from Boggy Meadows and almost continuously to the West Chesterfield area, a strip of coarse sediments lies against the eastern rock wall. If these sediments extend below river level as they do in the well described in sub-basin Q that is located just south of Walpole, they offer excellent possibilities for developing ground water in quantity, perhaps more than 5 mgd, in several areas. South of Canoe Meadow (opposite Putney Station) the coarse sediments extend to the rivers edge; here the probability of developing formations susceptible to recharge by the Connecticut seems excellent.

The large fairly level area extending from North Hinsdale, N.H., to Hinsdale appears to offer large storage potential. The few exposures seen indicate that coarse elements should be present. A well supplying North Hinsdale is located above the village on Lily Pond Brook yields 225 gpm with

42 feet of drawdown. It is unlikely that high discharge could be maintained here over a long period of time in view of the small recharge area and low storage potential. A test well drilled at the inner edge of the lowest river terrace on Ash Swamp Brook penetrated coarse sediments between depths of 30 and 46 feet. These beds probably do not extend below river level and although the site is better than that of the above-mentioned municipal well, it may not be possible to pump 1/2 mgd continuously here. Optimum results will depend upon locating permeable beds at greater depth that can be recharged by the Connecticut River. If such beds can be found, it should not be difficult to develop 5 mgd or more in the North Hinsdale-Hinsdale area.

Summarizing, the low ground flanking Connecticut River from Bellows Falls through Vernon offers some fair possibilities of developing ground water in quantity. Along the west bank, large supplies are available south of Brattleboro and small to moderate supplies at Westminster Station and (probably) Westminster, Putney and Vernon. On the New Hampshire side of the river coarse sediments are present from Boggy Meadows to West Chesterfield and in the North Hinsdale area. If these extend some tens of feet below river level, which is yet to be determined, very large quantities of water may be developed by constructing wells that will induce infiltration from Connecticut River.

Sub-basin R

Sub-basin R includes the West River drainage area, all of which is in Vermont. A large number of villages lie within the area; Weston, Londonderry, Jamaica, Wardsboro, Townshend and Newfane being among the larger of these.

Near the head of the system the valley passing through Weston (Wallingford, Vt., topographic sheet) to Londonderry (Londonderry, Vt., topographic sheet) is a fairly broad gravel fill area with good storage potential. At Weston a school well penetrates 35 feet of gravel and yields 30 gpm. The area around

Londonderry receives considerable recharge and should be a favorable location for developing up to 2 mgd if permeable sediments can be found at moderate depth.

Below Londonderry and as far as Jamaica the West River appears to have little gravelly fill except small areas around Thompsonburg and above South Londonderry. The valley of Winhall River, tributary to West River, does not appear very promising.

At Jamaica, Vt. Mr. Moyer reports that 75 feet of coarse clean gravel is present. Two miles below Jamaica 70 feet of gravel was penetrated. The wider valley area below Jamaica to West Townshend (Saxtons River, Vt., topographic sheet) should be productive of wells yielding 1/2 mgd or more. With moderate storage capacity and the flow of West River to draw upon for recharge, 4 or 5 mgd should be available in this reach.

Along Wardsboro Brook, wells the wider valley area at Wardsboro (Londonderry topographic sheet) might sustain a yield of 1 mgd from wells readilly enough.

From Townshend (Saxtons River topographic sheet) to Williamsville Station (Brattleboro topographic sheet) where Rock River joins West River, the valley is floored with glacial sediments and should provide good sites for wells. Wachussetts Drilling Co. personnel report that 2-1/2 miles north of Williamsville Station 55 feet of hard packed gravel was penetrated at the extreme right bank of the river. Up to 5 mgd might be developed here from wells.

The tiny Newfane Valley is more than 100 feet higher than the adjacent West River Valley. Probably only very modest well water supplies could be developed here. It is of interest to note that about 2 miles up Wardsboro Brook at a considerable higher elevation than Newfane a driller reports penetrating 90 feet of gravel in a domestic well.

Favorable gravel fill is seen in the Rock River valley above South Newfane and below Williamsville, Vt. Bedrock at South Newfane is more than 100 feet on the north bank of Rock River. Up to 1/2 mgd might be developed there and well over 1/2 mgd at Williamsville.

Below West Dummerston dam only fines were seen along the West River.

At Retreat Meadows, upstream from Brattleboro, the town supply is obtained from two shallow drilled wells, 60 by 48 inches in diameter. The one is 28½ feet deep and yields 457 gpm with 11 feet of drawdown. It is equipped with 8½ feet of 26-inch no. 120-slot screen in a double pack. The second well is 28 feet deep, has 5 feet of no. 120-slot screen and yields 1,000 gpm. The second well has only a single pack of pea gravel. Static level in the well varies with the height of West River.

Sub-basin S

Sub-basin S lies in New Hampshire and covers the drainage area of the Ashuelot River and its tributaries. The city of Keene is the largest center of population but Winchester and Hinsdale are important lesser centers.

Upper Ashuelot River lies in a somewhat broad valley that was a temporary glacial stream spillway. A few miles below Marlow (Lowell Mt., N.H., topographic sheet) it turns sharply westward through a rock cut channel (Bellows Falls, N.H.-Vt., topographic seet) and then sharply southward through a more open channel (Keene, N.H.-Vt., topographic sheet) to empty into the broad Keene area.

That portion of the Ashuelot River valley for 2 or 3 miles below Marlow might furnish more than 1/2 mgd sustained yield from wells.

The Surry Mountain flood control reservoir is located north of Keene in a fairly broad valley fill area. At times of flood flows of Ashuelot River, the volume of water retained by the dam is so large that it cannot be emptied in as short a period of time as might be desirable. If ground water supplies could be developed above the dam, water levels would be lowered somewhat there, thus providing space for absorbing at least a little of the flood flows.

The part of the valley just below the dam is known to be gravelly and the development of several wells yielding upwards of 1 mgd each might be easily accomplished. In the low lying area west of the city near the base of the hills a well 101 feet deep yielded 810 gpm with 19 feet of drawdown. Highly permeable gravel is reported beneath 160 feet of silt half a mile south of Wilson Pond, south of Keene.

The occurrence of coarse permeable gravels along valley walls, and in the valley north of Keene suggest that up to 20 mgd might be developed in the area without difficulty. The volume of water in storage is enormous and should provide ample reserve to carry over in periods of low rainfall. Coarse gravel stringers are probably present along the course of South Branch of Ashuelot River between Swanzey and East Swanzey and along the Ashuelot River from West Swanzey to Winchester. Test drilling will be necessary to locate aquifers but these should be present. Perhaps 5 mgd could be developed in the valley between West Swanzey and Winchester. The Winchester municipal well, located just north of Forest Lake, is 54 feet deep and yields 375 gpm with 10 feet of drawdown.

Sunny Valley, extending southward from Winchester into Massachusetts, should offer possibilities of ground-water development. Perhaps well over 1 mgd might be produced without drawing upon ground-water recharge from the Ashuelot River.

Around Hinsdale, at the mouth of the Ashuelot, gravels may be present under the cover of fine grained sediments now exposed at the surface. If they are found, heavily pumped wells would gain recharge from the Connecticut River as well as from the Ashuelot.

Sub-basin L-6

Area L-6 lies along the Connecticut River in northernmost Massachusetts and southern Vermont and New Hampshire and includes the small Falls River tributary that passes through Bernardston.

Generally speaking this is a poor ground-water province. Along the main stem of the Connecticut a thick section of lake sediments lies upon bedrock and coarse gravels are not known to be present. Below Mt. Hermon, 300 feet of fine sand or silt was penetrated in one well. Coarse sediments might be present at depth in the terraced area above Pioneer Valley Regional School (Northfield, Mass.-N.H.-Vt., topographic sheet). However, the drainage area is small and unless recharge from the Connecticut could be counted upon, probably not more than 1/2 mgd sustained yield should be anticipated.

On the eastern side of the river, coarse sediments at moderate depth have been penetrated in a test well along the mountain flank east of

Northfield, Mass., and in the reentrant in which Pauchang Brook lies but the probability that such sediments would lie deep enough to receive recharge from the Connecticut seems remote. Perhaps 1/2 mgd or so can be developed from two or more wells.

Sub-basin T

Area T covers the Millers River drainage basin within which cities and towns of Orange, Athol, Gardner and Winchendon, Mass., are located.

The small gravelly area along Darling Brook (Mt. Grace, Mass.-N.H. topographic sheet) may support a yield of 1/2 mgd.

A gravelly channel heading on the south side of Millers River extends southward through Lake Mattawa to the head of Quabbin Reservoir, a distance of about 6 miles (Orange, Mass. topographic sheet). The more favorable areas for considering well developments along this channel are on either side of Millers River and for a mile or more south of Lake Mattawa. The town of Orange has a well 75 feet deep on the south side of Millers River that yields 500 gpm. Depth to bedrock there is unknown inasmuch as the test hole was discontinued at "refusal" at 77½ feet. Not much ground water could be developed from wells located north of Lake Mattawa unless wells were able to induce infiltration from Millers River, in which case perhaps a total of 3 mgd might be developed without great mutual interference between wells. If alluvium across Millers River at West Orange extends below river level, probably 3 or 4 mgd can be developed there with ease.

Between Lake Mattawa and Quabbin Reservoir up to 4 mgd might be developed from several widely spaced wells but so doing would be diverting water from the reservoir.

A rather broad alluvial plain extends along the south bank of Millers River for $2\frac{1}{2}$ miles upstream from Orange and tapers southward to the head of Quabbin Reservoir. Much of this material underlying this plain may be silt or clay. However, it is thought that large glacial meltwater streams passed southward through the area and that coarse sediments should be present in one place or other. Development of ground water in large quantities will depend on the distribution of coarse sediments at depth, the effectiveness of local recharge, potentially as much as 8 mgd, recharge from Millers River and availability of the large volume of water that is in storage in the area. It seems likely that a minimum discharge of 5 mgd might be sustained in this area as long as some infiltration from Millers River could be expected.

The upper reach of the important glacial meltwater channel referred to above extends headward a very short distance to the east along Millers River through Athol (Athol, Mass. topographic sheet) and then northward up along East Branch of Tully River (Royalston, Mass.-N.H., topographic sheet) where it dies out. Coarse sediments have been encountered at moderate depth in several places in and north of Athol--one well there is reported to have yielded 2 mgd. No doubt high yield wells could be developed as far north of the city as Tully Dam. Underground storage potential is large here and recharge from East Branch of Tully River could be counted upon. Probably a discharge of from 5 to 10 mgd could be sustained from a well field in this area.

Above Tully Dam exploratory drilling would be necessary to define the ground-water potential but it is thought that the area immediately east of Tully Dam has possibilities for sustaining a discharge of 3 mgd without counting upon the recharge available from Tully Reservoir as such. Ground-water potential diminishes rapidly with distance up East Branch of Tully River in that storage capacity decreases and the recharge area becomes smaller. The area along upper reaches of Lawrence Brook, tributary to East Branch, is thought to be a poor area for ground-water development.

The swales extending southward from Athol, in which Lake Ellis and Riceville Pond are located, do not appear to represent an importnat glacial spillway. Hence only small discharge could be sustained from such permeable gravels as may be present from place to place.

One of the major glacial meltwater channels in the Eastern Highlands of Massachusetts heads in the Sip Pond-Damon Reservoir area in New Hampshire (Winchendon, Mass.-N.H. topographic sheet) and extends southward, passing west of both Winchendon and Baldwinsville and out of sub-basin T and into sub-basin V at the head of Burnshirt River (Templeton, Mass. topographic sheet). A very considerable volume of underground storage is available along this channel. Depth to bedrock southwest of Baldwinsville, for instance, is 97 feet. In the reach passing Winchendon and Baldwinsville recharge from Millers River and Otter River is available and local recharge can hardly be considered negligible. Assuming that test drilling proves the presence of permeable sediments at depth, it seems likely that a few tens of millions of gallons of water a day could be developed from the ground in the reach designated. Test drilling should explore one or more sections completely across the north-south channel and all holes should be continued into bedrock (rather than to "refusal") in order to determine where the maximum thickness of coarsest sediments may be.

To the south, in the valley from Crow Hill Brook to Stone Bridge Pond, (Templeton topographic sheet) storage potential is large but recharge is largely dependent upon local precipitation. Probably three or four widely spaced wells in this channel could sustain yields of up to 1/2 mgd each.

Glacio-fluvial sediment is widely spread in the area northeast of Winchendon through Lake Monomonack in New Hampshire and eastward from Winchendon through Lower Naukeag and Upper Naukeag Lakes in Massachusetts (Winchendon, Mass.-N.H. and Ashburnam, Mass.-N.H. topographic sheets). However, the topography suggests that this cover is thin and that relatively deep channel deposits are generally lacking. The best localities for exploration are immediately northeast of Whitney Pond and Winchendon along North Branch and immediately southeast of Whitney Pond along Millers River. In both these localities the present drainage system follows the glacial meltwater drainage lines. Channeling by glacial streams and accumulation of sediment was greater for a mile or so northeast and southeast of Lake Whitney than it was farther upstream in either direction. If somewhat deep coarse sands or gravels are present in the areas mentioned, a few million gallons a day should be available from each locality.

Glacial meltwaters also flowed southeastward temporarily from Baldwinsville (Templeton topographic sheet) along the present Otter River and then southward through the Gardner Airfield area and on out of the sub-basin. Large quantities of ground water can probably be developed between Baldwinsville and Gardner Airfield--storage and recharge potential are excellent--but again the task remains to locate deeper lying permeable beds. Assuming these are present, from 5 to 10 mgd should be available. Water-bearing beds should be present in the channel south of the airfield but recharge potential there is limited.

The low-lying area southeast of Gardner is thought to offer poor possibilities for development of ground-water supplies.

Summarizing, large quantities of ground water are available in the vicinity of Orange; in the channel in which Lake Mattawa is situated and also in the Orange Airfield area. At and north of Athol large well water supplies are available. Less may be available in the vicinity of Tully Dam. The prominent glacial drainage channel that passes southward west of Winchendon and Baldwinsville should be productive of enormous quantities of ground water. The low lying area east of Winchendon may yield only very small supplies. Along Otter River from Baldwinsville to Gardner moderately large to large volumes of ground water may be available.

Sub-basin U

Sub-basin U is that of the Deerfield River drainage system which extends from southwestern Vermont and down into northeastern Massachusetts.

The east branch of Deerfield River, for about 5 miles above Wilmington (Wilmington, Vt., topographic sheet), is a somewhat broad gravel filled valley in which well water supplies can probably be developed with ease. The recharge area is perhaps as much as 30 square miles, with annual average recharge in the nature of 10 mgd. Storage in the sand and gravels above Wilmington might well be over 2 billion gallons if bedrock lies at a depth of 50 to 100 feet in the lower reach of this small valley. Hence a sustained yield of several million gallons a day might be developed within a mile of Wilmington if the valley is largely gravel filled.

The adjacent west branch of Deerfield River, above Medburyville, Vt., is more deeply incised than the east branch and storage potential is less but patches of coarse sediment may permit construction of wells recharged almost directly by the river.

At Medburyville and just west of Wilmington, Vt., wells of any appreciable depth would tend to be recharged from the enormous Harriman reservoir to which these localities are immediately adjacent.

Gravelly deposits along the Deerfield River below Sherman Dam have a meagre development. However, just upriver from Shelburne Falls, Mass., a terrace, more than half a mile wide at its widest point (Ashfield, Mass. topographic sheet), flanks the river for a distance of about three miles. Where Clesson Brook crosses the terrace a well 120 feet deep failed to encounter bedrock and a domestic well at Charlemont, a short distance upstream, ends in gravels at a depth of 140 feet. The volume of ground storage here is large, recharge from the Deerfield River could be relied upon if heavily pumped wells were located here and, hence, this terrace area should be favorable for development of at least a few million gallons a day.

North River, a tributary to the Deerfield, offers excellent possibilities for development of ground water. A 250-gpm well located near Griswoldville, Mass., (Colrain, Mass.-Vt., topographic sheet) supplies water to the town of Shelburne Falls below. Another municipal well of comparable yield has been developed at Colrain. Wells of this capacity could be developed up along East Branch of North River almost to the Vermont line. The total amount of water that might be developed in any reach would be dependent to a large degree on the amount of infiltration of river water that would occur.

Underground storage volume here is fairly large and no doubt several million gallons of ground water could be developed along the lower reach of the river without difficulty.

The city of Greenfield obtains water from 3 wells in the terrace plains between Greenfield and Bernardston (Bernardston, Mass.-Vt., topographic sheet). In a normal season two of these wells yield 850,000 gpd each and the third well about 600,000 gpd. Alluvium extends to a depth of 120 feet or more in this area and hence storage volume is large. Local recharge conditions are excellent and recharge and some direct runoff from adjacent areas would be intercepted if ground-water levels were depressed by heavy pumping. Perhaps more than 5 mgd could be developed in the general area of Greenfield wells. If the entire terrace area that extends for three miles west of the Greenfield wells were developed by wells a total sustained yield of more than 10 mgd could probably be obtained. However, in the event of maximum development of this area, every effort should be made to develop wells in the general vicinity of Green River in order to take advantage of possible rapid recharge from that river.

The topographic trough between the Western Highland mountains and the trap ridges south of Greenfield in which the Deerfield River flows (Greenfield topographic sheet) may have particularly large ground-water potential. Water in underground storage might exceed 5 billion gallons per 50-foot thickness of saturated sediments in the $4\frac{1}{2}$ miles long by a mile wide area. Recharge from the Deerfield River may be available. However, only fine sands appear at the surface and nothing is known of the occurrence of coarse sands at depth. The Deerfield village supply is obtained from gravel in a 33-foot well that yields 163 gpm with 9 feet of drawdown. Seven-tenths of a mile south of the big bend in the Deerfield River (Greenfield, Mass. topographic sheet) a well on high ground encountered 529 feet of silt lying on bedrock (at 235 feet below sea level). However, this location marks the locus of the pre-glacial Deerfield River and it is thought that in most of the topographic trough referred to, depth to bedrock will be much less.

Total ground-water potential here might be reckoned in tens of millions of gallons a day. However, not only is the distribution of permeable beds at depth unknown but the effectiveness of recharge from the Deerfield River and from local rainfall is inhibited to some degree by the presence of the fine grained sediments seen at the surface. Therefore, for the present perhaps, the ground-water potential should be considered to be of the order of 5 to 10 mgd.

Small areas of glacio-fluvial sediment are present at Ashfield, South Ashfield and Conway along South River, a tributary to Deerfield River (Ashfield topographic sheet). Coarse sediments are present from place to place but considering the limited storage potential the maximum total discharge that might be sustained in these areas may range from 1/2 to 1 mgd.

Summarizing, in the headwater area of the Deerfield River, moderately large supplies of ground water may be available in the valley north of Wilmington as well as just west of that town. Downstream, unconsolidated sediments in which wells can be developed are patchy in distribution. Favorable well sites are present above Charlemont and on both sides of the river around East Charlemont. In the vicinity of Connecticut River test drilling will be necessary to show that the wide terrace on which Old Deerfield is located is a favorable area for large ground water developments. The terrace area north of Greenfield can be developed to a much greater degree than it is at present.

The valley of North River, tributary to the Deerfield, is a favorable area for moderately large ground water developments. Relatively small well water supplies are available from place to place along South River.

Sub-basin L-8

Area L-8 extends from near Turners Falls to Holyoke and includes the drainage area of several small rivers in Vermont, two of which are named

Mill River, and several small rivers in New Hampshire, one of which is also named Mill River. It includes the drainage area between the Deerfield and Westfield River basins west of Connecticut River and between the Millers River and the Chicopee River basins east of Connecticut River.

Little is known of the makeup of the formations that underlie the broad low terraced area extending from the northward bend of the Deerfield River (Greenfield topographic sheet) southward through Whately and Hatfield, Mass., (Mt. Toby topographic sheet) to Northampton (Mt. Holyoke topographic sheet). It is known that bedrock lies deep in some places; at 235 feet below sea level near the bend of the Deerfield River just north of this sub-basin and at 245 feet below sea level in the area being discussed four-tenths of a mile south of South Sugarloaf Mountain, i.e., southeast of South Deerfield. On the low terrace east of the city of Northampton a well drilled at the easternmost city limits encountered bedrock at 66 feet below sea level. In each of these localities only lake clays and silts were found to be present above bedrock. However, there is reason to believe that before and even during the lake stage, spill from the Deerfield River was deposited along the flank of the Western Highland and that water-bearing deposits are present there at depth. The high terrace deposits west of Westbrook are predominantly gravelly. However, they may bottom out in bedrock before any appreciable thickness of saturated beds is penetrated. The possibility that the toe of these deposits or similar older deposits are present at depth along the western margin of the lower terraces seems good and worthy of exploration. From a long range point of view, it would seem desirable that a series of four or five borings be put down to bedrock beginning at, say, the south end of the village of Hatfield and eastward to the Connecticut River in order to assess the ground-water potential of the area. Eighteen square miles of possible aquifer is involved in which as much as 18 billion gallons of water in storage may be present in the first 50 feet of saturated sediment and in which local recharge might range up to 20 mgd in a year of normal precipitation. Additional recharge from the highlands or the Connecticut River would add greatly to the potential of the area under conditions of heavy pumping. However, not only are data lacking on the presence or absence of aquifers but the effectiveness of recharge to possible aquifers beneath a generally silty to clayey cover is unknown. Hence, figures given above are not estimates of available ground-water supply but, rather, dimensions to be considered when additional data make estimates possible.

Florence, Mass., just west of the city of Northampton, is situated where Mill River enters the open terrane of the Central Lowland (Easthampton topographic sheet). When the lowland was ice clogged in the late stages of ice decay the flow of Mill River at first turned sharply southwestward at Florence but subsequently continued almost 2 miles farther southeastward before turning south and passing through the city of Easthampton. With deposition in this latter path by debris brought in by the heavily laden glacial streams the bed elevation of the river rose until it became possible for Mill River and the Connecticut itself to flow through the gap it now follows between Mt. Tom and the Holyoke Range.

Along Mill River at Florence bedrock was encountered at 78 feet below the surface at the Prophylatic Brush Company. The well yields 900 gpm with 35 feet of drawdown from Basal gravels. The nearby city of Northampton wells yield, respectively, 700 and 900 gpm. Those wells encountered bedrock at 111 feet.

Whether the temporary spillway of Mill River leading southwestward from Florence would be productive of ground water in quantity is problematical. Even if high yield wells could be constructed there storage and recharge potential are somewhat limited and two or three million gallons a day might be all that could be sustained from several widely spaced wells.

According to the sequence of events sketched out above coarse sediments should be present somewhere in the old Connecticut River (and Mill River) channel leading south-southwestward from Northampton through Easthampton to Pequot Pond. A well in the center of this channel at the north end of Lower Mill Pond, Easthampton, developed 200 gpm from a 2-foot aquifer under 81 feet of silt. On the Maloney property, about half a mile northeast of that locality, clay was penetrated to a depth of 130 feet, below which the section was largely medium to coarse sand to a depth of 205 feet. The hole was discontinued in clay at 208 feet. According to R.E. Chapman Company records, a 8-inch well here yielded 825 gpm with 69 feet of drawdown. Nearer the base of Mt. Tom Range, directly east of the city, a test well on the Terry property penetrated 128 feet of clayey sediments, at which depth the hole was discontinued and a well on the Loomis property encountered clay to 100 feet and largely fine sand to 215 feet. Whether or not coarse sands and gravels may be present at greater depth is not known.

Two wells at Daly Field at the south end of the city have a combined yield of 2 mgd but actual pumpage is reported to be 1,000 gpm.

At the eastern margin of the channel less than two miles south of town (Mt. Tom topographic sheet) a battery of one hundred and twenty seven 2-1/2-inch flowing wells of various depths and two larger diameter wells supply the city of Easthampton with 2-1/2 mgd of ground water. A log supplied by R. E. Chapman Company shows that the section is largely coarse sands and gravels from 20 to 106 feet. Bedrock was encountered at 118 feet. A 10-inch well here about 100 feet deep yields 1 mgd.

About 3 miles south-southwest of Easthampton, a well encountered bedrock at a depth of 321 feet which is 90 feet below sea level. According to Mr. C. Yurgielewicz, a local driller, this record confirms the southward extension of the pre-glacial channel. However, coarse sediments were lacking at that particular location.

About 6 billion gallons of water may be in storage in 50 feet of saturated sediments in the channel between (roughly) Easthampton and Pequot Pond. Local recharge may be in excess of 6 mgd. Some additional storage and recharge from the west would be available by underground flow from the west to wells located in the general vicinity of Plain Street which is about one and one-half miles southwest of Easthampton. Total available ground water should range from 5 to 10 mgd.

The ground water potential along the southern extensions of the higher spillway of Mill River across North Branch of Manhan River and along Manhan River itself (Easthampton topographic sheet) and southward (Mount Tom topographic sheet) through Southampton along the N.Y., N.H. & H. RR and the headwaters of Moose Brook is undoubtedly large.

The Southampton municipal well, 1-1/2 miles northeast of the village, develops 10 feet fine and coarse sand lying upon bedrock at 140 feet. The well, 8 inches in diameter, yields 550 gpm with $85\frac{1}{2}$ feet of drawdown. One-half mile south of this well, on Gunn Road, bedrock was encountered at a depth of 200 feet. The section was presumably fine at this location which is on somewhat higher ground. A mile and a half southeast of Southampton, sandy sediments in Moose Brook Valley are developed in two domestic wells at 121 and 142 feet respectively. At the very head of Moose Brook gravel was encountered in a domestic well at 90 feet.

Gravels are present at moderate depth from place to place in this channel, underground storage is large (the area of glacial and lacustrine sediments is 8 miles long and a mile wide in places), recharge from local rainfall is fair and recharge from adjacent highland areas, in part via the Manhan River system, is of considerable importance. The problem here, as in so many areas, is to locate the thicker permeable beds well below the water table. Assuming that geological conditions are favorable for development of high yield wells, perhaps a ground-water discharge of 10 mgd could be maintained here too.

In the Western Highland portion of sub-basin L-8, there is a small accumulation of gravel in a cove along Mill River at Williamsburg, Mass. (Williamsburg topographic sheet). A 78-foot deep well there yields 500 gpm. Perhaps up to 2 mgd sustained yield could be developed in this locality.

In the Westhampton area (Westhampton, Mass., topographic sheet) an accumulation of sand to coarse gravel 5 miles long and about half a mile wide is present as filling of a longitudinal valley. Recharge to sediments in and around the village of Westhampton may be in the nature of 8 mgd in a year of normal rainfall. However, topography is such that the major fraction of this recharge crosses the area as streamflow and is discharged via North Branch of Manhan River and Turkey Brook. Whether heavy pumping in the glacial fill would intercept a good part of this flow is problematical. Considering this unknown factor and the somewhat limited storage available, efforts to develop more than 1 mgd in the Westhampton area may or may not be successful.

That portion of sub-basin L-8 lying east of Connecticut River extends from Wills Hill, south of Turners Falls, southward through South Hadley (Brimfield, Mt. Toby and Mt. Holyoke topographic sheets).

The wide terraced area just south of Willis Hill (Greenfield topographic sheet) is underlain by approximately 200 feet of fine sand or silt according to Mr. E. Hartley, a local driller. It is not known whether coarse sediments are present along the mountain flank, more or less along State Highway 63, but considering the data furnished by drilling at Montague (below), that area seems worth exploring.

South of the broad terraced area mentioned, a rather narrow valley leads southward on the east side of Mt. Toby to North Amherst. This valley marks the spillway of Millers River, and perhaps the Connecticut as well, at a late glacial stage when the central valley was still filled with ice.

A 117-foot deep well near the base of the Eastern Highlands and east of the village of Montague encountered 7 feet of highly permeable gravel beneath a cover of silt. The water is under strong artesian pressure, possibly as a result of the head of water built up in the adjacent higher lying coarse gravels against which the silts lie. A yield of 421 gpm with 39 feet of drawdown has been developed in the well but at higher discharges, silt from the overlying beds is drawn in and the water becomes silty. Assuming that similar "mechanical" problems are not encountered, it seems likely that several wells yielding 1 mgd might be located here and along the base of the highlands to the north.

In the narrow valley leading southward from Montague the thickness of the formations is unknown and the extent to which recharge from adjacent mountain masses might take place is likewise unknown. It is much less evident that large supplies are available here.

At the lower end of the valley referred to above, two miles north of North Amherst, 80 feet of deltaic gravel is exposed in active gravel pits near State Highway 116 and Plum Tree Road (Mt. Toby topographic sheet). At the very toe of the cliffs in which the gravel pits are developed, a test well drilled for the city of Amherst encountered bedrock at a depth of 376 feet, that is, 146 feet below sea level. Coarse water-bearing sand was penetrated between 35 and 65 feet, fine sand and grey clay to 290 feet, red clay to 345 feet and red till to 376 feet. A producing well nearby that is 76 feet deep yields 1 mgd. A domestic well located about one-half mile south-southeast of Plumtree Road encountered fine-grained sediments to a depth of 137 feet till to a depth of 213 feet and highly permeable gravel between 213 and 220 feet. Bedrock was reached at a depth of 233 feet in an adjacent well.

In considering the recharge available from high ground to the east and the storage available up valley as well as in the bordering low terrace formations to the west, it is obvious that the ground-water potential is excellent in the general vicinity of the Amherst wells. Perhaps a yield of 5 mgd could be sustained from wells in this immediate area.

The southward extension of coarse sediments of the Millers River delta south of Mt. Toby is indeterminate. The town of Hadley has constructed two wells four miles to the south, just east of Mt. Warner, that obtain, respectively, 400 and 700 gpm from gravels at a depth of about 200 feet. What the possibilities might be of finding permeable beds in the intervening area cannot be said without much more data.

Temporary drainage from the Millers River in an early stage of ice decay did continue southeastward along the flank of the mountains. The stream flowed down the valley a mile and a half east of Amherst and passed through the gap east of the Holyoke Range (Belchertown topographic sheet). South of this gap, in which Lake Arcadia is located, temporary flow may have passed west of Belchertown, east of Belchertown or southwest from Arcadia Lake. In fact flow may have occurred in all of these spillways.

The 10-mile length of this channel, from below the deltaic gravel pits above North Amherst to Arcadia Lake, should offer excellent possibilities for developing moderate supplies of ground water from place to place. Again, no data are available pertaining the subsurface formations and about the best that can be said at the moment is that from 1 mgd to 5 mgd may be available from one or more wells at various locations and that the amount of discharge that could be sustained is dependent not only on the presence of coarse beds at depth but on the opportunity for recharge and the available storage at any particular locality.

A mile west of Dwight (Belchertown topographic sheet), that is, along the outer edge of the channel outlined above, the city of Amherst has two wells less than 100 feet deep that together yield 2 mgd. A nearby domestic well penetrated very little permeable material above bedrock that was reached at a depth of 137 feet.

The wide terrace area bordering Connecticut River that extends from Sunderland to the north slope of the Holyoke Range (Mt. Toby topographic sheet) is thought to be a poor area generally with respect to ground-water supplies although, as noted above, the Hadley wells are located out on that terrace. However, permeable beds are believed to be very erratically distributed in this area and further evaluation cannot be made at this time.

The area at and downstream from the Connecticut River gap between the Mt. Tom Range and the Holyoke Range (Mt. Holyoke topographic sheet) is one of special interest. At Thermopylae, on the west bank of the river immediately below the gap, the town of South Hadley has a 113-foot well that yields 1 mgd. The section is clayey to 93 feet and sandy to gravelly between 96 and 113 feet. Till was penetrated in the bottom of the hole. On the opposite side of the river, the Holyoke Water and Power Company has three wells that have a combined yield of over 3 mgd. It is believed that preceding the lake stage, drainage from the upper basin poured through this gap and upon losing velocity below the gap deposited some or much of its heavy debris load. The river did not follow its present path below the gap at the time, rather, it trended south-southeastward, perhaps meandering as far eastward as Westover Air Force Base before turning westward again. However, coarse sediments would tend to be localized in the area a short distance south-southeast of the gap, perhaps no farther to the south than the area immediately west of South Hadley. From the point of view of developing the largest possible supply of ground water, the area along the east bank of the Connecticut for about one mile below Thermopylae should be explored first. Here opportunity for recharge from the Connecticut would be at a maximum. The amount of well water discharge that could be sustained would depend largely upon the ease with which the deep lying aquifers were recharged by the river. Assuming that coarse sediments are distributed downstream beneath the clayey cover and that recharge does occur somewhat readily, possibly 10 mgd might be developed without difficulty in the limited area noted.

It is believed that only domestic supplies can be developed elsewhere in the area south of the Holyoke Range within sub-basin L-8.

Summarizing, the ground water potential of the broad terrace along the west bank of the Connecticut from the Deerfield River to Northampton is problematical but may prove to be very large. Large yields have been developed along Mill River at Florence. The glacial drainage channel leading southward from Florence through Southampton would undoubtedly be productive of large supplies from place to place. The buried channel at the western base of Mt. Tom, from Easthampton southward to the limits of the basin, is highly productive of ground water supplies. Much smaller supplies are available at Williamsburg and Westhampton.

On the east side of Connecticut River the broad terrace from Turners Falls to Mt. Toby is unpromising except where the unconsolidated sediments lap against the Eastern Highlands. Deltaic beds just south of Mt. Toby are highly productive; their southward extension may be marked by the Hadley wells west of Amherst. Early glacial streams passed along the base of the mountains from Mt. Toby to the Lake Arcadia area. Here the prospects for developing moderate supplies of ground water are good. However, most of the area between Mt. Toby, the Holyoke Range and Connecticut River cannot be evaluated on the basis of information at hand.

Ground water prospects are excellent southeast of the gap between Mt. Tom and the Holyoke Range but are poor in the remainder of the area in sub-basin L-8 south of that range.

Sub-basin L-9

Sub-basin L-9 is that area along the Connecticut River that includes the cities of Holyoke, Springfield and Long Meadow, Mass.

In Holyoke bedrock is encountered at about 100 feet below the surface. A log supplied by Layne New England Co. indicates that the section is a clay, sand and gravel mixture from 28 to 47 feet and a fine sand to gravel mixture from 47 to 87 feet. Although difficulty was experienced in stabilizing the formation a yield of 805 gpm with 28 feet of drawdown was obtained from a 12-inch diameter well. The well is located along the Connecticut River near the foot of Davis Street. It seems likely that the formation would be recharged by the river under continuous pumping conditions.

The areal distribution of the aquifer developed in the Holyoke well is unknown and would have to be determined by test drilling if additional large supplies were sought. Ground-water potential at Willimanset, just south of Holyoke on the east bank of the Connecticut, should also be considered with reference to the Holyoke aquifer referred to above.

As far as is known, there is little or no possibility of developing large quantities of ground water from the unconsolidated sediments in most of the Springfield area. However, along the Connecticut just north of the city, a gravel stratum 55 to 63 feet below the surface was developed in a well that yields 250 gpm. Again, as at Holyoke, the distribution of such lenses is probably very erratic and further ground-water development in the area must be predicated upon the results of test drilling.

The small part of area L-9 southeast of the village of Agawam, Mass., on both sides of the Connecticut River may be underlain by water-bearing sand or gravel. However, the formations are lenticular here and several test wells 250 to 300 feet deep may be necessary to show that that area has or does not have a favorable ground-water potential.

Sub-basin V

Sub-basin V lies in the Eastern Highlands of Massachusetts and includes the drainage area of the Chicopee River and its tributaries, the two most important of which are the Ware and the Quaboag Rivers. The Quabbin Reservoir also lies within this sub-basin. Water released from that reservoir flows via the Swift River to the Chicopee.

Headwaters of Ware River are in the northeastern part of sub-basin V and are shown on Barre and Wachusett Mtn. topographic sheets. The present day streams are laid in old glacial spillways, through some of which once flowed great debris-laden meltwater streams. Deposition along some of those old spillways has resulted in unusually favorable ground-water conditions in many places. Permeable sediments are present that will permit construction of high yield wells, large volumes of water are present in underground storage, local recharge conditions are rather good and recharge from through-flowing present-day streams ranges from fair to very large.

The channel along East Branch of Ware River that extends diagonally southwestward from Mare Meadow Reservoir to New Boston (Wachusett Mt. topographic sheet) is one of the minor spillways. Glacio-fluvial deposits may not be very thick there but nevertheless coarse sediments may furnish two or three hundred gallons of water a minute to wells sited in the deepest part of the channel.

From the village of New Boston to Long Pond (Paxton topographic sheet), the valley is broader and somewhat thicker fill may be present. A continuation of this valley passes southward from Long Pond through Browning Pond (Paxton and North Brookfield topographic sheets), past the village of Spencer (East Brookfield topographic sheet) and then out of the Connecticut basin. However, the valley is not considered to be a particularly favorable area for ground water development except perhaps for a mile or two above Spencer.

Three 2-inch test holes were drilled along Cranberry River about a mile south-southwest of Spencer in which gravels were penetrated at 42 to 52 feet, at 51 to 61 feet and 51 to 63 feet. Whether even more permeable gravels are present at greater depth is unknown because the test holes were drilled by the jetting ("wash well") method and presumably were discontinued at "refusal." However, a recently completed production well here has a yield of 265 gpm.

Melt waters from the Gardner-Templeton area also flowed southward through Stonebridge Pond at the head of Burnshirt Creek (Templeton topographic sheet), past Hubbardstown via the valley of West Branch of Ware River, Stevens Brook (Barre topographic sheet) and continued on southward through Dean Pond and Brooks Pond (North Brookfield topographic sheet) to Lake Lashaway at East Brookfield, a distance of 19 miles (from Stonebridge Pond). Where the saturated sandy sediment in the valley is one-half mile wide and fifty feet thick each linear mile will contain about 2,600 million gallons of water in storage. In each mile of reach, the recharge area is much wider than the valley itself, perhaps one and one-half miles wide generally in this area, for which local recharge would be in the nature of 1 mgd. In most areas small streams and brooks would bring in some water from outside any particular one-mile reach and further, lowering of water levels by sustained pumping would help capture what is now reject water and would reduce evapotranspiration. South of Williamsville, small to moderate supplies of water, say, up to 1 mgd should be available along each linear mile of reach of this spillway if exploratory drilling shows the presence of permeable beds at moderate depths. Larger supplies will be available where recharge from major streams can be relied upon, as for instance, where East Branch of Ware River crosses the channel three miles south of Hubbardtown (Barre topographic sheet). Here 4 or 5 mgd might be developed if suitable permeable beds are present in the meltwater channel.

It seems likely that somewhat larger supplies, 4 or 5 mgd, might also be developed in the reach above East Brookfield and as far north as Brooks Pond, a distance of more than 3 miles. The volume of underground storage here is larger than in the valley to the north and surface water from Lake Lashaway would also tend to percolate toward heavily pumping wells.

Shallow wells on the west shore of Lake Lashaway that supply East Brookfield with water are probably recharged from the lake. Two 12-inch diameter wells there are 24 feet deep and yield 140 gpm each. A dug well there that is 16 feet deep yields 300 gpm.

The meltwater channel described above continues southward from Lake Lashaway through Quaboag and Quacumquasit Ponds, beyond which it passes out of the basin. The lake and ponds mark places where huge ice blocks lingered in the waning stages of deglaciation. However, it may be presumed that during the earlier stages, debris laden meltwater streams passed by these ice blocks and that coarse sediments were deposited in their channels. It is suggested that channel gravels may more likely be present on the east banks of Lake Lashaway, Quaboag and Quacumquasit Ponds rather than on their west side. At a later stage the broad open area from East Brookfield to Brookfield became a pond in which fine sand and clay were deposited from which only meagre water supplies may be obtained. However, along the main meltwater channels, as outlined above, coarse sediments are probably present.

Assuming that permeable sediments can be located, a reasonably large part of the average flow of Quaboag River might be captured by wells in this area. Underground and surface storage is very large, average recharge should be of the order of 10 mgd and additional water should be available by surface flow and underground flow from outside the immediate Brookfield-East Brookfield-Quaboag Pond area.

However, the distribution of water-bearing beds is almost unknown and until their presence is established an estimate of the volume of available ground water cannot be made. Some test drilling has been carried out in the area but the most favorable locations were not chosen and holes were not continued to bedrock. It is emphasized again that test drilling in glacial sediments should be done by the cable tool method (1) for accurate sampling and (2) to be certain that the complete geologic section is penetrated. Too often "wash drill" test holes are discontinued wherever penetration becomes difficult.

As noted above, the glacial meltwater channel in which Burnshirt River flows begins at Stone Bridge Pond below Baldwinsville, continues southward through Williamsville past its junction with Ware River and then trends southeastward at Coldbrock Springs (east of South Barre) to join the channel that leads to East Brookfield. However, at a somewhat later stage this early channel to East Brookfield below Coldbrook Springs (Barre topographic sheet) was abandoned and the present channel of Ware River westward to South Barre was followed.

As much as 120 feet of alluvium is present in the short north-south valley leading from Barre to South Barre. Near the end of that valley the town of Barre has constructed a 65-foot well that yields 250 gpm. Opportunity for recharge is not great but is undoubtedly great enough to sustain several wells of that capacity.

At South Barre and southwestward to Wheelwright, Ware River lies in a broad valley filled with glacial sands and gravels (Barre, North Brookfield and Ware topographic sheets). At South Barre bedrock was encountered in a test well at a depth of 140 feet. A production well 50 feet deep has a yield of 1,080 gpm. At Wheelwright clean pea gravel was encountered in a domestic well between 65 and 80 feet according to Mr. A. F. Scales, driller, of Rutland, Mass. In the reach between South Barre and a point 1 mile southwest of Wheelwright storage water in the alluvium alone may be as much as 8 billion gallons (estimated on the basis of 50 feet of saturated sediments), local recharge may be in the nature of 8 mgd and there is every reason to consider that recharge from Ware River would take place under heavy pumping conditions. No doubt up to 10 mgd could be developed here with ease and perhaps larger quantities could be developed.

Below Wheelwright a temporary glacial spillway leads southward (Ware topographic sheet), passes on both sides of Whortleberry Hill but merges again and leads into Wickaboag Pond on the north side of West Brookfield (Warren topographic sheet). The channel may contain a good fill of permeable sediment but recharge is limited in that no large streams flow along or across the channel. It is thought that a discharge of perhaps one mgd per mile reach of channel might be sustained. Test drilling in the area just north of Wickaboag Pond was carried out in 1960-61 and it was said that a satisfactory water supply was not located. However, in one of the many 2-1/2-inch test holes sand and gravel was reported between 41 and 54 feet and a yield of 60 gpm was obtained. Water level was 2 feet below the surface. The writer is inclined to believe that in a properly developed 8-inch well equipped with a 6-inch screen of optimum slot size, several hundred gallons a minute might be developed there. Test hole #18 nearby was sandy and gravelly all the way down to 57 feet. Seemingly excellent yield might have been developed there too. Further, neither test hole, nor any of the 26 holes drilled, were continued to bedrock and, therefore, in spite of all the drilling, it cannot be said that additional highly prolific water-bearing beds are not present at greater depth. An older 12-inch diameter well, drilled in 1951, 56 feet deep, is located on the south shore of Wickaboag Pond (Warren topographic sheet) and yields 600 gpm with 15 feet of drawdown. The grain size of the formation is undoubtedly large in that the 15 feet of screen installed is 250-slot size. This well is probably recharged from Wickaboag Pond.

Not much more can be said about the potentialities of the area until a few properly located wells are drilled on down into bedrock. However, it seems likely that several million gallons a day might be developed above Wickaboag Pond where recharge from the pond and upstream recharge, as underflow or as surface flow via Sucker Brook and Mill Brook could be counted upon.

The broad swampy valley of the Quaboag River that extends from West Brookfield (Warren topographic sheet) southeastward through Brookfield to Quaboag Pond (East Brookfield topographic sheet) is unexplored. Coarse sorted alluvium may be present here at moderate depth but there are no indications to suggest that this is so. Some test drilling was carried out by the town of Brookfield (East Brookfield topographic sheet) in a short tributary valley north of the town with disappointing results. However, even though the test holes (maximum depth penetrated by the drill was 54 feet) failed to indicate the presence of thick highly permeable beds, it cannot be said that these are absent in the area because the holes were not continued on to bedrock, as is usually done where test drilling is performed by a cable tool machine. If further test drilling is carried out in this area, it is suggested that it may be better to explore possibilities along the Quaboag River Valley, rather than in the valley north of Brookfield.

It seems clear that for a time meltwaters during the latter stages of deglaciation flowed southwestward from Wickaboag Pond and West Brookfield (Warren topographic sheet), and then turned south at Warren and spilled out of the present basin into the Brimfield area. The village of Warren has three wells just south of town; in # 2 well gravel extends from the surface to 42 feet and medium sand from 42 to 92 feet below the surface. The well is equipped with 20 feet of 20-slot screen and yields 150 gpm with 22 feet of drawdown. Reasoning from these data, it seems likely that a longer screen of larger slot size in a similar sediment might result in a well of considerably higher capacity. A 68-foot well drilled nearby yields 129 gpm.

Recharge to the Comins Pond area where the Warren wells are located is about 3 mgd.

Two and one half miles south of Warren, the village of West Warren has a 25-foot diameter dug well 24 feet deep and a gallery 60 feet long, 20 feet wide and 18 feet deep. The discharge is not known. There seems to be little reason to think that the community of West Warren could obtain deep well water closer to the village. In Warren, a domestic well on Whiskey Road penetrated shallow gravels and then continued in silt to bedrock at a depth of 170 feet.

Returning to the present valley of the Ware River (Ware topographic sheet), the somewhat narrow reach from below Wheelwright to Gilbertville and Ware most likely contains coarse fill from place to place. In a test drilled for the village of New Braintree, south of Ware River just upstream from Gilbertville, coarse sand and gravel was found to a depth of 41 feet at which point drilling was discontinued. A yield of 120 gpm was obtained from a 8-inch diameter well in this locality. Parenthetically, the village of New Braintree might find it advantageous to consider the ground-water potential in the alluvial valley that leads directly southward from Wheelwright. If water can be developed in that valley, pipeline to New Braintree would be about one mile as opposed to more than three miles at the locality near Gilbertville.

In the area just upstream from Gilbertville but on the north side of Ware River, the village of Gilbertville has developed a supply of 115 gpm from a 39-foot well. Medium gravel was encountered between 33 and 39 feet. The well is equipped with 5 feet of 60-slot screen and has a drawdown of 27-1/2 feet at the discharge noted. A nearby test hole encountered silt and clay to a depth of 56 feet (at "refusal") and it is not known whether or not additional aquifers are present at greater depth.

No doubt yields of 1/2 mgd per individual well could be developed in many places along this reach of river and in some places higher yields could be developed. However, the full thickness of valley fill should be explored rather than relying upon what may be present in the first 50 feet. Recharge from Ware River should be available in most instances.

Another fairly broad sediment filled valley leads southward from Athol into Ware. The portion of this channelway north of Quabbin Reservoir (Petersham topographic sheet) appears to be poor with respect to ground-water supplies. Nevertheless, small supplies may be available in places, as, for instance, in the broad open area just west of Petersham.

The 8-mile reach of the valley above Ware (Ware topographic sheet) appears to have carried a much larger stream at one time than Muddy Brook which now occupies it and it is thought that moderate ground-water supplies may be available here. Recharge of about one mgd per mile of reach of the brock should be available without counting upon possible underflow from the Quabbin Reservoir. Test wells half mile south of Hardwick Pond encountered bedrock at fairly shallow depths, however, and the ground water potential above Ware is yet to be demonstrated.

At Ware 40 tubular small-diameter wells have been drilled that range in depth from 18 to 42 feet. Total yield is said to be about one mgd. More recently a well equipped with 5 feet of no. 80-slot and five feet of no. 120-slot 18-inch diameter screens, developed 520 gpm with 16 feet of drawdown from coarse sediments that extend to 51 feet below the surface. The well is located in the valley just south of Snow Pond.

Southwest of Ware the broad valley of Ware River winds through a complex of rounded hills (Palmer topographic sheet) and is joined by the Quaboag River coming in from the west, at which junction it becomes the Chicopee River. Glacial meltwater drainage in this area flowed generally southward across the present drainage lines and passed out of the present basin via Foskett Mill Stream to Brimfield and through the valley that extends southward from Palmer through Monson.

From West Warren and southward to a point about three miles east of Palmer the Quaboag River flows in a narrow channel in which very little sand or gravel may be present. This narrow section of valley may have been ice jammed until a late stage of melting. The north-south valley just to the west that passes east of Pattaquattic Hill was not a major drainageway and likewise offers rather poor possibilities for ground-water development.

The north-south valley leading southward from Quabbin Reservoir through Beaver Lake, Forest Lake, and Thompson Lake more than likely passed southeastward through Fentonville to Brimfield. This valley was a major drainageway and moderate to large ground-water supplies should be generally available in this channel north of Palmer.

On the north shore of Forest Lake 80 feet of gravel was penetrated without reaching bedrock. At nearby Camp Mohegan rock was encountered at 110 feet. Twenty feet of #60-slot screen was installed in a well there which is said to have yielded over 100 gpm with "very little" (less than 2 feet) drawdown according to Mr. P. Romanik, a local driller. Just south of Thompson Lake one well encountered fine sand from the surface to a depth of 50 feet and till from 50 feet to 129 feet at which depth bedrock was encountered. However, a very short distance to the west excellent water bearing gravels were found at the elevation at which fine sands were penetrated in the first well and in another nearby well permeable gravel was encountered a few feet above bedrock.

In two or three locations where this channel crosses Quoboag River east of Palmer only fine sands have been penetrated down to bedrock.

Another well defined channel leads southward from Quabbin Reservoir along the course of Swift River to Bondsville where it is joined by another meltwater channel that passed southeastward from Belchertown. South of Bondsville meltwater drainage flowed through Palmer and southward to Monson. By the time this Palmer-Monson spillway opened up, the higher gap to Brimfield was abandoned.

Excellent water-bearing sands and gravels have been found in the upper portion of the Swift River channel a mile or so south of Quabbin Reservoir. At the Massachusetts Fisheries and Game Commission installation a mile south of Quabbin Reservoir a 48-foot deep well, 8 inches in diameter, yields 550 gpm. A well of about the same depth at Robin Farm camping ground a mile to the south developed a yield of 300 gpm.

In the open area in which Bondsville and Three Rivers are located, the glacio-fluvial formations are thin in places and much fine material is present below a capping of gravelly beds. Both towns mentioned have developed municipal supplies from shallow wells. At Bondsville 250 gpm is obtained from six 2-1/2-inch diameter wells about 40 feet deep. At Three Rivers one shallow well field yields 200 gpm and another 270 gpm. It is altogether likely that coarse channel deposits are present from place to place beneath a veneer of fines but careful test drilling to bedrock will be necessary to locate those deposits. The area immediately downstream from the narrow passes west of Palmer Center (not Palmer) and west of Mt. Dumplin might be particularly worthwhile testing.

The town of Palmer has developed a supply of about 400 gpm from a battery of 19 two-and-one-half inch wells 40 feet deep that draw water from gravels overlying fine sand. Just west of Allen Pond in Palmer 100 feet of fine sediments lie upon bedrock. Just east of that pond the section is similar. According to P. Romanik, a local driller, an industrial well was developed there in the shallow gravels that yielded 50 gpm with 10 inches of drawdown or about 300 gpm with 29 feet of drawdown. If deep-lying coarse sediments are present in this area, they probably lie along the south bank of the river.

In the channel about a mile south of Palmer only clayey sediments were found but between North Monson and Monson (Monson, Mass.-Conn. topographic sheet) gravelly sediments are present from which one well obtained a yield of 330 gpm. Half a mile south of South Monson well sorted gravels were encountered at a depth of 60 feet. Two miles south of South Monson 72 feet of sand and gravel was penetrated. The town of Monson has a well 75 feet deep that yields 812 gpm with 30 feet of drawdown. At an industrial plant two wells have a combined yield of about 1-1/2 mgd. Probably several million gallons a day additional sustained yield can be developed in the area north of Monson. South of Monson the recharge area is small.

The valley from Lake Arcadia (Belchertown topographic sheet) extending southeastward east of Belchertown and into the Bondsville area was undoubtedly a meltwater channel for a time. However, no deep hole data are available that show the character of the valley fill at depth.

East of Belchertown a battery of 40 small diameter shallow wells is reported to yield a total of 400 gpm from coarse gravels overlying fine sediments.

A less well defined valley extends southward from Arcadia Lake and passes west of Belchertown to the Chicopee River. However, it seems likely that the spillway here and the spillway east of Belchertown referred to above were late glacial stream courses and it is possible that only fine sediments were deposited in them.

Development of water in large quantities in the valleys passing generally southward on either side of Belchertown would affect the water available to Springfield Reservoir (Ludlow topographic sheet) and to the Chicopee above the Red Bridge Dam. However, under some circumstances this might be desirable if wells of moderate depth were able to discharge underground storage water not available to the reservoirs by normal flow.

No particularly encouraging information is available regarding ground-water potential in the valley of the Chicopee River. Bedrock lies fairly close to the surface in places (Peterson and Maevsky p. 10, 21) and in other places the valley fill is not water bearing. On the east bank of the Chicopee just north of the Massachusetts Turnpike (Ludlow topographic sheet), a well at an elevation of 290 feet encountered 210 feet of till above bedrock. The Construction Service Co. well on the south bank of Chicopee River and about a mile west of North Wilbraham encountered bedrock at a depth of 220 feet, that is, at about sea level. Although 573 feet deep it is open to question whether the 110 gpm yield reported comes from bedrock or not. Personnel at the plant have suggested that modifications in the original well were made to permit entry of water from basal sands or gravels. A representative of the R.E. Chapman Co. stated that in test drilling at nearby Spectacle Pond, bedrock was encountered at about 112 feet below the surface and that a favorable thickness of permeable gravels was penetrated.

At the Banas Sand and Gravel operations less than a mile north of Ludlow 180 feet of red clay lies upon bedrock. Bedrock here lies at 60 feet above sea level but at Ludlow rock occurs in the river bed, at about 160 feet above sea level. At Indian Orchard, just west of Ludlow (Springfield North topographic sheet), a 40-foot well in sand and gravel yields 200 gpm and, also in that vicinity, two gravel-packed wells near Fivemile Pond that are 57 feet deep have a combined yield of 160 gpm. Data on other wells farther to the west show that bedrock is generally high in the area. However, on the south bank of the Chicopee where it joins the Connecticut, bedrock lies 162 feet below the surface or about 112 feet below sea level. This record lends support to the findings of a seismic survey that indicated that bedrock lies at about 125 feet below sea level a short distance to the north, where the Massachusetts Turnpike crosses the Boston and Maine Railroad.

The broad open valley extending southward from North Wilbraham, Mass., (Ludlow, Mass., topographic sheet) will hardly be productive of more than small supplies of water. Depth to bedrock ranges from very little to as much as 100 feet in some places but the total thickness of sediment present is not very great, the sequence is interrupted by till from place to place and the only recharge available is local recharge. Probably a few wells yielding up to two hundred gallons a minute each might be sited there.

Summarizing, large supplies of ground water are available in sub-basin V where thick glacial sediments were deposited in old spillways that led south or southeastward out of the area and where those permeable beds are susceptible to ample recharge.

The channel from Mare Meadow Reservoir southward to New Boston, through Long Pond and past Spencer will be productive of only rather small yield wells except perhaps near New Boston and Spencer.

Another channel begins as Burnshirt River valley, crosses Ware River at Coldbrook Springs and trends south to Lake Lashaway and Quaboag Pond in the vicinity of East Brookfield. It should be highly productive at and north of Coldbrook Springs and in the East Brookfield area but only moderately productive elsewhere. A tributary channel beginning at Brigham Pond near Hubbardstown joins this channel below Coldbrook Springs. It lies at a higher elevation and may contain only a thin fill of water-bearing sediments.

The valley between Barre and South Barre is susceptible to further moderate ground water development. Along Ware River from South Barre to

Wheelwright very large volumes of ground water can be developed and prospects seem rather good almost as far downstream as Gilbertville.

The glacial channel from Wheelwright and southward to Wickaboag Pond and West Brookfield should be productive of moderate supplies of ground water. From West Brookfield southeastward to Quoboag Pond (East Brookfield) good aquifers may be present but further data are necessary to characterize the area. From West Brookfield southwestward to Warren moderate to large supplies of ground water should be available but south of Warren the volume of water available decreases progressively with thinning of possible aquifers and diminishing recharge potential.

The Ware River valley from below Gilbertville to Ware appears to offer good opportunity for development of moderately large ground water supplies. The glacial spillway heading south of Athol and joining Ware River valley at Ware appears to have good ground water possibilities along Muddy Brook above Ware but more drilling data are necessary to show that this is so.

A prominent glacial channel leads southward from Quabbin Reservoir, through Beaver Lake, along a portion of Ware River, through Forest Lake to Palmer and out of the basin southeastward to Brimfield and southward through Monson. Moderate to large supplies are available along this channel except in the low-lying Palmer (Quoboag River valley) area.

A parallel channel leading out of Quabbin Reservoir lies just to the west of the channel mentioned in the preceeding paragraph. It contains prolific aquifers in the two-mile reach south of the reservoir.

The Belchertown-Bondsville area may be underlain by narrow stringers of coarse sediments from which high yields can be obtained but this is yet to be demonstrated.

The area around Ludlow, Indian Orchard, Chicopee Falls and Chicopee will not be productive of large well water supplies, except, possibly, near Connecticut River.

Sub-basin W

Sub-basin W includes the area drained by the Westfield River and its tributaries. By and large there are no large accumulations of permeable sediments in the middle and upper reaches of this system. Narrow fringing terraces are present from place to place but in many instances these do not extend below river level and the volume of ground water that can be developed from them is very small indeed. Where alluvium or glacio-fluvial deposits do extend below river level and water can be developed from beds below river level, infiltration from the adjacent stream or river will occur under heavy pumping conditions and large supplies will be available. However, because storage is very limited pumpage will be essentially limited to that portion of the actual low flow of the river at any time that infiltrates the ground in the vicinity of the wells. Reliance may not be placed on a proportion of the average base flow of the river, as is commonly possible.

In the lower reaches of the Westfield River there are several areas in which large volumes of ground water might be developed. The area extending from Westfield northward through Pequot Pond was part of a major glacial drainage system. Two miles north of Pequot Pond bedrock was encountered at a depth of 321 feet (about 90 feet below sea level). At the south end of Pequot Pond (Mt. Tom, Mass. topographic sheet) highly permeable gravel was encountered between 250 and 280 feet and other gravel lenses in an otherwise fine grained section have been penetrated in domestic wells in the general vicinity of Pequot Pond at depths of 81, 90, 135 and 147 feet.

The city of Westfield has two 24-inch diameter gravel packed wells located north of the Westfield River and east of the city that are pumped at a rate of about 2 mgd each. No. 2 well on fairly low ground encountered bedrock at 121 feet. The lower 25 feet of section was screened with no. 30 to 60-slot screen, after which the well was pumped and surged for 365 hours. The 8-inch "test well" previously installed had yielded almost half as much water (610 gpm) as the final production well. This well is located only 15 feet or so above the level of the Westfield River and presumably would be recharged by flow from that river if water levels were lowered sufficiently by heavy pumping. Well No. 1, of the same depth, is located on higher ground and would probably not induce recharge from the river.

The town of West Springfield has a battery of 2-1/2-inch wells just northeast of Westfield well No. 1, from which about 400 gpm is obtained.

Underground storage in a 50-foot thickness of saturated sediments in this area should be something in the nature of 6 billion gallons. (Greater volumes of storage water are available but to recover that water would require pumping lifts in excess of, say, 70 feet below the surface. The wells themselves however, might necessarily be much deeper than an assumed pumping limit of 70 feet.) Recharge from local precipitation might be as much as 8 mgd in a normal year. Lowering the water table by heavy pumping would diminish transpiration somewhat and help capture some water now rejected by the ground. Lastly, near the Westfield River some recharge would take place from that river, even through the silt and clay cover lying above the deeper aquifers, if ground-water levels were lowered by heavy pumping in the general vicinity of the river. Maximum development of ground-water resources here would be accomplished by developing the maximum volume of water for constant use from wells located near the Westfield River and relying on the ground storage pumped from widely spaced wells north of that locality for carryover in periods of low flow. The total ground-water supply that might be developed here and sustained over a long period of drought might be 10 mgd or more. Considerable test drilling would be necessary to define the critical hydrologic factors in the area and to permit proper planning of a large ground-water supply system.

Pumping from deep wells north of Pequot Lake would cause the ground-water divide to move northward, thus bringing in some water that now moves northward via Broad Brook. If high yield wells can be constructed about a mile west of Pequot Pond, some water that escapes via Moose Brook might be captured. A domestic well near the head of Moose Brook is finished in a gravel stratum at 91 feet and other data on wells to the north suggest that ground water in reasonable quantity can be recovered there.

A fairly deep channel may be present more or less along the line of the N.Y., N.H., & H. R.R., north of Westfield. If a favorable thickness of sediments is present there, 2 mgd might be developed without relying upon infiltration from the Westfield River.

Between Westfield and Little Rivers, just south of the city, the Westfield Gage Company has an 8-inch 35 foot well that yields 120 gpm with 5 feet of drawdown. It is equipped with 5 feet of no. 100-slot screen.

During the slow melting of the stagnant continental glacier, the central lowland was ice blocked and at least some of the Highland drainage at first flowed southward along the flank of the highlands passing through what is now Granville reservoir and Granville (Southwick, Mass.-Conn. topographic sheet). A little ground water might be developed in that area. A lower temporary drainage spillway just to the east, along the north-south reach of Munn Brook would be more worthwhile exploring. However, even here a million or two gallons a day sustained yield might be all that could be counted upon. A 70-foot well at the south end of this reach (south of State Highway 57 and Loomis Street) yields 400 gpm. However, whether much more than this volume of discharge could be maintained at that particular spot under continuous pumping conditions is doubtful in view of ground storage and recharge conditions.

If it is found that glacial stream deposits are thick in the vicinity of Little River into which Munn Brook empties, considerable underground storage should be available and, further, recharge from Little River and Munn Brook is likely. Development of an additional two or three million gallons a day there seems possible. The trend of Westfield River meltwaters southeastward out of the Western Highlands (Woronoco, Mass. topographic sheet) to the vicinity of Mundale cannot be exactly defined on the basis of data at hand but if it can be located, wells in that temporary channel near the Westfield River would induce infiltration from the river and from the ground-water reservoir to the south.

At a still later stage of melting but before the final disappearance of the ice in the deepest part of the central valley, that is, east of the trap ridges (Provin Mountain and East Mountain), the Westfield drained southward through the Congamond Lakes area (Southwick and West Springfield topographic sheets). A series of ice blocks lingered where the lakes are at present. A great flow of water down the channel presumably passed on either side of the ice blocks mentioned and it is altogether likely that permeable sediments were deposited along this temporary spillway from which large quantities of water can be drawn. The city of West Springfield has a group of seven wells here (West Springfield, Mass.-Conn., topographic sheet) along Great Brook, ranging in depth from 41 to 141 feet. A 41-foot well yields 675 gpm (about 1 mgd) and a 137-foot well yields 1,400 gpm (about 2 mgd). Total yield developed from the 7 wells is around 4 mgd. The city of Westfield is presently completing construction of two wells farther to the north on Great Brook from which yields of 2 mgd each is expected. Local recharge is calculated as about 10 mgd for the low-lying area and another 3 mgd from the adjacent hilly area to the west.

The depth of fill in the channel extending from Westfield River southward through Congamond Lakes is unknown. The area is 1-1/2 miles wide and 7 miles long. Underground storage in a 50-foot saturated thickness would be in the nature of 18 billion gallons, an amount of water that is more than sufficient to supply several high-yield wells during three or four years of sub-normal recharge. Further, heavily pumped wells located near the north end of the channel would induce recharge from the Westfield River if a cone of depression were created that reached that river. A ground-water development here of more than 10 mgd seems quite possible.

The area east of the trap ridges, in general the region including West Agawam, O'Briens Corner, Bowles-Agawam Airport and Agawam (West Springfield, Mass.-Conn. topographic sheet) is of considerable interest with respect to ground-water potential. During the very last stages of glacial melting a lake (Glacial Lake Hitchcock) inundated the area. During that time the debris laden Westfield River continued to flow into the lake and deposited its load of coarse sediment along the advancing shores of the lake. As the lake level rose higher and higher and extended farther and farther inland, the coarse sediments were buried beneath clays and silts deposited in the quiet lake waters. Hence, beneath the cover of fine sediments in the area mentioned, coarse water-bearing beds should be present from place to place. Representatives of R.E. Chapman Company report that good aquifers are present at depth along Westfield River directly north of the town of Agawam

(Springfield South, Mass.-Connecticut topographic sheet). One test hole was discontinued at 110 feet, having penetrated sand and gravel at 43 to 73 feet and from 78 to 110 feet. Highly permeable gravels were also penetrated in test holes to a depth of 124 feet on the north side of Westfield River just west of the Exposition grounds.

Just to the east of the Agawam location mentioned above, data supplied by Geraghty and Miller, Consultants, show that below a clayey stratum from 23 to 65 feet, the section is sandy. Coarse sands are present from 65 to 78 feet and from 120 to 132 feet. Along Route 57, one-third and two-thirds of a mile west of South End Bridge, bedrock was not encountered at 120 feet below sea level. Here, too, sandy sediments lie beneath about 75 feet of clay.

The presence of highly permeable gravel beneath lake clay and silt at a depth of 80 feet at North Thompsonville, Connecticut, on the eastern side of Connecticut River and 4 miles south-southeast of Agawam, suggests that a finger-like extension of the buried delta is present there. The irregular areal distribution of such deposits is shown by the record of a well one and one-half miles south-southeast of Agawam (on the east bank of the Connecticut) that penetrated only silt and clay to a depth of 247 feet. Bedrock was not reported at that depth which is almost 200 feet below sea level.

The course of the Westfield River immediately below the gap in the basalt ridges during and preceding the lake stage is problematical. The main flow may have passed southeastward through Agawam but, less likely, it may have taken a course more to the south-southeast. In any event, in spilling out past its hard rock walls, it wandered back and forth as its path tended to be impeded by deposition of its load of coarse sediments. It is suggested that three or four test holes drilled in a line from Liswell Hill northeastward to Westfield River (West Springfield, Mass.-Conn. topographic sheet) would yield enough information to show that more or less widespread coarse sediments should or should not be present to the east and southeast.

The total volume of water that might be available in the West Agawam-Agawam area would depend in large part upon the ease of infiltration of water from the Connecticut and Westfield Rivers. The amount of ground storage that is available to wells and local recharge, up to 3 mgd, would be subordinate factors. Assuming that permeable beds are widely distributed and that infiltration from the river occurs readily, the amount of ground water available would be reckoned in a few tens of millions of gallons a day.

In summary, considerable ground water should be available north, south and southwest of Westfield, and in the West Agawam-Agawam area. A maximum of 27 mgd is suggested as available from local recharge and much more may be available if recharge from Westfield and Connecticut Rivers occurs with relative ease. However, the estimate is based on somewhat scanty well data and much geological reasoning and considerable test drilling will have to be carried out before the maximum amount of available ground water can be produced.

Sub-basin L-10

Sub-basin L-10 encompasses a large area adjacent to the Connecticut River that extends from the Massachusetts-Connecticut state line to just below Middletown. On the west the area is bounded in large part by the prominent basalt ridges but to the east the area includes part of the Eastern Highlands.

The northwesternmost part of the sub-basin is that area drained by Stony Brook and its tributaries. Stony Brook enters the Connecticut River about a mile above Windsor Locks. Ground-water potential in this area is generally poor because much of the area to the west is broken up by low linear hard rock ridges and the cover of sediment is thin and in the area nearer the Connecticut River the sediments are largely lake silts and clays. Well data in the area are meagre--many of the wells that were constructed are located on the linear hard rock ridges and very little data is available on the thickness and type of material in the intervening shallow valleys. However, it is worth noting that on North Grand Street, just south of the Massachusetts-Connecticut state line (West Springfield, Mass.-Conn. topographic sheet) coarse sand and fine gravel was penetrated from 30 feet to bedrock at 112 feet. The well was continued into bedrock which supplies a small volume of water to the well (Cushman and others, 1964, p. 24). It is thought that conditions are especially favorable here only because a meltwater stream passing through a minor spillway in the basalt mountain at Harts Pond a mile to the west brought in coarse sediments that accumulated in the general area of the well described. An alternative possibility is that these sediments were deposited by a stream from the north.

Subordinate gravel filled channels passing south or south-southeastward through the Bowles-Agawam Airport area in Massachusetts may be present beneath the cover of lake sediments but their existence can only be established by test drilling in critical locations.

In the Farmington River delta east of the basalt ridge, several wells have been drilled in the vicinity of Bradley Field, Connecticut, that yield from 100 to 300 gpm (Windsor locks topographic sheet). Some gravelly sediments are present here but their thickness is not great and the total available drawdown in wells here is also limited. As an example a 68-foot well between Bradley Field and Windsor Locks obtained 330 gpm when the pumping level was drawn down to the top of the screen at 58 feet. Static water level in the well is 27 feet. In most instances the pumping level in producing wells in this general area cannot be lowered enough to induce infiltration from the Farmington River and the total sustained yield from a battery of moderate yield wells would be rather small. Recharge would be figured here as about 1 mgd per square mile although in any somewhat dispersed group of wells underflow from adjacent areas could be counted upon to some little extent.

Downstream from Bradley Field, at Thralltown, Conn., gravel was encountered between 74 and 88 feet in a highway test boring. It is overlain by lake silts and underlain by 10 feet of medium to fine sand. The gravels here lie well below the level of the adjacent river and recharge from the river might be expected under heavy pumping conditions. The volume of water slowly percolating down through a few square miles of silty cover to recharge an underlying blanket - like coarse formation might be very large in many circumstances. However, the ground water potential of this area is essentially an unknown quantity.

The well-defined channel that extends south-southwestward from Hartford through Newington and Berlin, Conn., was a spillway when the lower portions of the Connecticut trough was ice jammed and may contain well sorted coarse sands and gravels beneath the clay beds that were deposited in the later lake stage.

Along the west bank of the Connecticut River from Rocky Hill to below Middletown coarse sediments have been found in wells from which high yields have been developed. At Rocky Hill coarse sand and gravel extends from the bed of the river (2 feet below sea level) for 38 feet and a little coarse material is present at slightly greater depth. However, this material may be recent river deposit rather than a glacio-fluvial sediment. The Ranney type collector installed is reported to yield 4,200 gpm. On the River Road, on the downstream side of Middletown, the city has constructed two wells. The first well, 57 feet deep, yields 757 gpm with 14-1/2 feet of drawdown, the second well, 63 feet deep, yields 925 gpm with 18 feet of drawdown. Both wells are 24 x 18 inch gravel pack wells equipped with 10 feet of screen at the bottom of gravelly sections about 20 feet thick.

Although overlain by lake clays and silts, the wells stabilized after only three hours pumping. It seems obvious, therefore, that these wells must receive recharge from the Connecticut River, perhaps by some circuitous path upon being put into production as does the Ranney type well at Rocky Hill.

At the CANEL Site, located on a terrace of the Connecticut River downstream from Middletown and opposite Middle Haddam, a test well yielded 1,570 gpm with a drawdown of 13.7 feet (Baker and others, 1965) and a yield of 3,000 gpm per well seems possible. The investigation demonstrated that the well is hydraulically connected with (recharged by) the Connecticut River. According to pumping test data and within the area available, it was estimated that the potential capacity of the well field is in excess of 20 mgd

The extremely valuable conclusions made were based on a careful study and analysis of data collected during two 48-hour pumping tests. Two different wells were pumped successively and water level data collected from 13 observation wells during and after the pumping. Numerous other data were also collected.

The manner in which the investigation was conducted and the facilities employed illustrates that time, effort and money are required for a thorough investigation. More important for the purpose of this report, it shows under the conditions at the CANEL Site, infiltration from an adjacent stream does occur under heavy pumping conditions and that the quantity of well water that can be developed under some circumstances is very large.

Turning now to the east bank of the Connecticut, the northern part of sub-basin L-10 is that small area drained by three small streams discharging at or above Thompsonville, Connecticut (Springfield, Mass.-Conn. and Broad Brook, Conn. topographic sheets). Bedrock lies at moderate depth here and is overlain by lake clays and silts. Certain notable exceptions are made to this generalized statement in that the old deep channel of the Connecticut River passes through the area and in some places water-bearing sediments have been encountered that yield very prolifically indeed.

Flint (1933) and Cushman (1964a, p. 18) have shown that the pre-glacial course of the Connecticut River lies about two miles east of its present course in Connecticut. In the area presently being considered bedrock lies fairly high (60 feet below sea level) just east of North Thompsonville (well 20, Cushman and others, 1964, p. 10). However, this boring is thought to have encountered bedrock on the west wall of the old pre-glacial channel. In Massachusetts, a mile or so north of Mass.-Conn. State line, a well along the river penetrated 33 feet of sand and gravel below which silt and clay extends to a depth of 247 feet (195 feet below sea level), apparently withoutl reaching bedrock. The well is presumed to have been drilled in the deeper part of the pre-glacial channel of the Connecticut River. (The present writer believes that from here the pre-glacial Connecticut River trended northwestward nearly to the present Westfield River and then directly westward through the gap in the trap rock ridges near Westfield.)

Is the old pre-glacial channel of the Connecticut River the locus of permeable sediments from which large ground-water supplies can be obtained? The writer thinks that it is not, except by chance. It seems quite evident that ice in the deep troughs was the last to melt. Coincident with or immediately following the melting of the deep lying ice in the old valley axes, the area was covered by waters of Glacial Lake Hitchcock. Thus, just preceding the lake stage the old deep channels would tend to be filled with fine grained material brought in by now less turbulent streams characteristic of the very late stage of ice dissipation or by clays and silts of the succeeding lake stage. However, where the axes of the old channel lies in the path of major tributaries that continued to spill coarse sediments into the old channelway before and during the lake stage, good ground-water prospects may exist. Cushman and others have recorded a well (well EF 44, 1964a, p. 11, 22) less than a mile northeast of North Thompsonville that produces 1,300 gpm with less than 40 feet of drawdown. The well is equipped with 3 feet of Everdur plate perforated with slots 1/2-inch wide and 1 inch long. Lake clays were penetrated to a depth of 25 feet, below which the section was gravelly to a depth of 80 feet. In the adjacent test well gravelly sediments were penetrated between 55 and 75 feet below which clay and fine sand extended to 105 feet and sandy gravel to 120 feet. The logs indicate that coarse material was being carried out into and deposited in a lake whose level was gradually rising. It is thought that the sediments may be a finger-like extension of a Westfield River delta now covered by lake clay that is present in the Agawam, Mass., area (sub-basins W and L-9), as discussed above. Data presented by Peterson and Maevsky and by Cushman, as well as data obtained during the present study, suggest no compelling reason to believe that the sediments are part of a Chicopee River delta.

Summarizing, the two wells discussed above show first, that the old pre-glacial channel north of the state line does not contain coarse sediments and secondly, at North Thompsonville coarse sediments are present along what is presumably that old channel. Further, the permeable sediments penetrated at relatively shallow depth at North Thompsonville seemingly owe their presence to their location relative to the Westfield River delta rather than to the deep channel.

No other large yield wells have been developed in the general area north and west of Thompsonville and it seems likely that large supplies could not be developed unless the extension of the probably stringer-like sand near North Thompsonville could be located to the northwest or south, at best a risky task.

In the broad lowland along the Connecticut River from Thompsonville southward to East Windsor Hill, Conn. there are no ground water developments worthy of particular comment. However, it is worth noting that a 180-foot commercial well just west of Hazardville penetrated twenty five feet of gravel at the base of an otherwise silty and clayey section. Bedrock was not encountered although the well reached a depth of 45 feet below sea level. Other wells in the area encountered little or no gravelly sands even though several are located more or less along the axis of the pre-glacial Connecticut River channel.

On the higher terrace along Graham Road about two miles east of East Windsor Hill (Manchester topographic sheet) near the base of the highlands 500 gpm was developed in a 52-foot well. Although the well has a high yield, it is questionable whether a discharge at this rate could be maintained indefinitely inasmuch as the bottom of the well is only 20 feet below the level of the terrace to the west. However, if the stratum extends a few tens of feet lower, a considerable amount of storage water and recharge area could be drawn upon. Exploration along the base of the hills seems warranted.

At East Windsor Hill bedrock is encountered at 145 feet below sea level (Well SW-62, Cushman and others, 1964, p. 16) indicating that the pre-glacial channel has veered westward. South of East Windsor Hill it may trend parallel to the Connecticut, within half a mile of that river, but at the northern limits of East Hartford the channel turns directly southward. At the northern limits of East Hartford 20 feet of sand was found lying upon bedrock in the old channel which was reached there at a depth of 240 feet, that is, at 190 feet below sea level. When screened and developed the well yielded 500 gpm with less than 93 feet of drawdown. Another well located in the old channel of the Connecticut River is near Rentschler Airport about two miles farther south. Here 10 feet of sand was found near bedrock which was struck at 295 feet. Gravel was present from 255 to 265 feet, clay from 265 to 287 feet and silty gravel from 287 to 295 feet (245 feet below sea level). A yield of 250 gpm was developed from the upper gravel.

The headwaters of the Scantic River (Hampden, Mass.-Conn. topographic sheet) are laid in a broad flat valley within the Eastern Highlands that extends southward from Wilbraham, Mass. to Somers, Conn. At Somers the river turns westward and discharges thru a gap near Somerville and enters upon the low terraced area bordering the Connecticut River. The broad valley above Somers is not an area where large supplies of ground water can be developed. Bedrock is known to lie within a few tens of feet of the surface in several places and good aquifers are not commonly present. Recharge that would help sustain a discharge of a few million gallons of well water a day might be expected along Scantic River but the presence of good aquifers and a reasonably large volume of available storage water is not apparent.

The village of Hampden, Conn. lies in a small gravel filled basin within the hills just east of the broad valley referred to above. Bedrock is encountered at shallow depth and it seems unlikely that more than domestic supplies could be obtained there.

The broad valley trending southward from Wilbraham, Mass. narrows two miles below Somers Conn. but broadens again to the south in the Ellington area. The pass between Somers and Ellington, a temporary glacial meltwater spillway, is about two miles long and less than half a mile wide. There are no data to show that water bearing beds are better developed there than in the broader valleys to the north or to the south. In any event, recharge and underground storage in the immediate area is very small and therefore even if highly permeable sediments were present, perhaps not more than a million gallons a day sustained discharge could be developed.

The broad area around Ellington (Ellington topographic sheet) and its continuation as a broad to narrow valley southward past Rockville (Rockville topographic sheet) to Talcottville and Manchester, Conn. (Manchester topographic sheet), still within the Eastern Highlands, appears to be a more promising area hydrologically than the northward reach of this spillway discussed above. Data at hand (Cushman and others, 1964, p. 10) show that bedrock lies as deep as 125 feet at the village of Ellington. However, no logs of wells are available and not a great deal can be said of the geology of the 6½ mile valley extending from around Ellington to Talcottville. Nevertheless, there may be possibilities of developing ground water there in moderate quantity. Local recharge from precipitation may be of the nature of 6 mgd and in the lower part of the valley some additional water from adjacent areas is available. Underground storage may be large. Hence, up to 5 mgd sustained discharge might be developed here, assuming that geological conditions are reasonably favorable.

At Talcottville, which is just north of Manchester, a 57-foot well penetrated only sandy and gravelly sediments to a depth of 57 feet (Cushman and others, 1964, p. 25) but was not continued to bedrock. Other wells in the immediate vicinity encounter bedrock at depths ranging from 90 to 136 feet. This area seems to be a promising area to prospect for moderate supplies of water. Just to the west of Talcottville and a short distance off the main glacial spillway (now occupied by Hockanum River) a 10-foot stratum of gravel was penetrated between 50 and 60 feet below the surface in which a well with a yield of 350 gpm was developed with 26 feet of drawdown.

Southwestward from Talcottville the spillway channel widens out along Hockanum River and in part passes the northwestern city limits of Manchester. At this point it seems that glacial meltwater stream flowing down present Hockanum valley spilled northwestward as well as southwestward to the lowland area below East Hartford. At the intersection of Wilbur Cross Highway and the Tolland Turnpike one mile northwest of Manchester city limits, a well penetrated fine to coarse sand from 69 to 200 feet and gravelly sand from 200 to 223 feet, below which bedrock was penetrated. This well was completed at a depth of 65 feet and developed a yield of 250 gpm with 25 feet of drawdown. On the north side of Hockanum River and near the northwestern city limits of Manchester, a well drilled for the Manchester Water Department penetrated 25 feet of dirty sand and gravel below which was 40 feet of clean sand and gravel. The well is equipped with 15 feet of screen and yields 750 gpm. At the westernmost city limits 450 gpm was developed from a coarse sand stratum penetrated between 45 and 65 feet below the surface. Sand and gravel is reported in a 110-foot well about a mile southwest of the city limits. Unfortunately, a log is not available.

The data given in the preceding paragraph show that the old spillway from Talcottville southwestward past Manchester is a particularly favorable area for development of high yield wells. The total amount of water available will depend on effectiveness of recharge from local precipitation, the availability of recharge water from Hockanum River, a major stream, the amount of storage that is present in the area influenced by pumping and the distribution of permeable sediments from which wells can draw water. Inasmuch as the conditions cited appear favorable to some degree, it seems likely that more than 10 mgd may be available here.

The valley of Tankerhoosen River, a tributary to Hockanum River which it joins at Talcottville, extends northeastward to the shores of Shenipsit Lake. This valley was also a glacial meltwater channel. A considerable thickness of sediment has accumulated at the south end of Shenipsit Lake. According to the log of a boring made during highway construction, fine red sand extends from the 13 feet to 85 feet below the surface. These data suggest that the sediments are lake sediments and that coarse grained aquifers may not be present. However, down the Tankerhoosen valley nearer Talcottville, it seems likely that meltwater streams should have deposited coarse permeable gravels in which high yield wells could be developed. Tankerhoosen River drains a large area and recharge conditions should be excellent in the reach extending a mile east of Tankerhoosen lakes. A minimum of 5 mgd should be available here.

A very narrow temporary channel extends southward from Tankerhoosen valley near Talcottville and passes southeast of Manchester. A 33-foot well in this channel yields 300 gpm by siphon. Recharge here is limited.

In the glacial channel that passes southeast of Manchester city limits, the city has two wells respectively 60 and 52 feet deep that yield 600 and 560 gpm. In the second well all the material penetrated was coarse grained sediment. The wells are located in an area susceptible to only moderate recharge but underground storage is fairly large. Perhaps up to 5 mgd is available here from the ground.

It is quite apparent from the records of wells that have been drilled in the vicinity of Manchester that the permeable glacial sands and gravels are widely distributed and that it should be possible to develop a great deal more water than has been done so far. By siting wells in locations where considerable underground storage is available and where recharge from major streams will occur readily, it is thought that as much as 25 mgd might be developed here with ease. The greater portion of water pumped should be taken from wells located in the Hockanum River valley as far up as Talcottville and in the lower reach of Tankerhoosen River valley. The area directly east, southeast and south of Manchester is recharged by local precipitation and underground storage volume is much smaller and much less ground water can be developed there.

The glacial meltwater channel that passes southeast of the city of Manchester (Glastonbury topographic sheet) leads southwestward along the course of Roaring Brook, passes through East Glastonbury and empties onto the lowland area bordering the Connecticut River at South Glastonbury. At an early stage of deglaciation the meltwater drainage in this channel spilled southeastward (rather than westward to East Glastonbury) across a high level divide. With melting of the ice in the Central Lowland spillways westward to Glastonbury and South Glastonbury became effective.

The meltwater channel extending southward from Manchester must be considered as a separate hydrologic unit because there is a hydrologic divide just south of that city. The channel beginning a mile or so south of Manchester is a broad sediment filled valley in which excellent water bearing beds are probably present. However, very large quantities of water could not be developed there because recharge is limited to that derived from local precipitation. Somewhat farther south, along Roaring Brook from Buckingham, Conn., to a point two miles southwest of East Glastonbury, Conn., prospects for developing moderate supplies of ground water seem good. A total of 3 mgd could probably be obtained from several wells located just above and just below East Glastonbury and perhaps an additional million gallons or so per day could be developed below East Glastonbury near the intersection of Roaring Brook and Cold Brook.

As noted above, some of the meltwater drainage also flowed out of the Manchester-Buckingham channel toward Glastonbury, more or less along Salmon Brook. The presence of deep sediment filled channels here seems somewhat less obvious, yet there may be a good chance of developing a million or two gallons a day if a fairly deep channel can be located. The area south and southwest of Treat Pond appears to be a choice location for exploration wells if the need for water in that area arises. Recharge from Salmon Brook should recharge the aquifers and a not inconsiderable amount of underflow would be expected from sandy sediments extending northward towards Manchester.

Well records and borings at hand do not suggest that deltaic formations are present at moderate depth where the Salmon Brook and Roaring Brook enter upon the lower ground bordering Connecticut River. From East Hartford to South Glastonbury sediments penetrated in deep holes at the foot of the Eastern Highlands are largely fine grained (Cushman and others, 1964, p. 23). On the other hand, in a well developed for the town of Portland, Conn., to the south, 66 feet of coarse grained sediments were encountered above bedrock from which a yield of 400 gpm was developed.

Coarse sediments are not present along the Connecticut River at Portland as they are on the Middletown side of the river, as is evident from the sandstone quarries for which Portland is famous and from the record of borings made recently for bridge footings.

The old preglacial channel of the Connecticut River that passes east of Portland through the Jobs Pond area is an area of some small ground water potential. South of Jobs Pond 126 feet of sand and gravel are reported in a domestic well. At a depth of 188 feet which is 38 feet below sea level, bedrock was not reached although in a nearby well it reached at 65 feet below sea level. Development of water in quantity here would require that good aquifers be present well below sea level in order that recharge from Connecticut River be available under heavy pumping conditions. This can only be determined by further test drilling and all that can be said here is that it may be possible to develop small to moderate quantities of water in the channel passing through Jobs Pond.

Summarizing, on the lowland west of the Connecticut River from Bowles-Agawam Airport and southward through Hartford, ground water conditions are generally unfavorable. Small supplies have been developed at Bradley Field and just south of Farmington River. It may be possible to develop small to moderate supplies in the glacial channel extending from Hartford to Berlin.

Large yield wells along the Connecticut from Rocky Hill to below Middletown are recharged by the river. Still larger developments are possible.

On the low terraced area east of Connecticut River from Connecticut state line to East Hartford an excellent aquifer was encountered near North Thompsonville but extensions of this aquifer or other good aquifers are not known in this area. Moderately large supplies of ground water can be developed in the East Hartford area but below that city prospects are poor.

Only meagre supplies are available in the valley above Somers. Prospects around Ellington are poor but southward to Talcottville the ground water potential is somewhat better.

In the Hockanum valley from Talcottville and downstream past Manchester, in the tributary valley of Tankerhoosen River and along Hop Brook south of Manchester ground water conditions are favorable and a very large supply can be developed in the area.

A moderate supply of ground water should be available in the headwater area of Salmon Brook (north of Buckingham) and fairly large supplies can be developed in the broad valley passing through East Glastonbury.

Sub-basin X

Sub-basin X lies in that part of the Western Highlands and western part of the central lowland that is drained by the Farmington River and its tributaries, the most important of which are the Mad, the Nepaug and the Pequabuck. The short section of the river flowing across the Connecticut River floodplain to the Connecticut is not included.

In the upper reaches of West Branch of Farmington River small areas of gravel are present around North Otis, Otis and at Cold Spring, Mass. (Otis, Mass. topographic sheet). However, unless the sands and gravels are thicker than they appear to be, only very small quantities of water may be developed from them.

Southward, unconsolidated deposits are present in the narrow valley below New Boston, Mass., (Tolland Center, Mass.-Conn. topographic sheet). Much of the sediment here may be recent river gravel (alluvium) rather than glacial valley train deposits and may not extend much below river level. However, if the alluvium is thick enough to permit construction of high yield wells, recharge from the river could be counted upon. From Riverton, Conn. (Winsted, Conn. topographic sheet) to New Hartford, Conn. (New Hartford topographic sheet) glacio-fluvial deposits are somewhat more widely distributed along West Branch, particularly around Riverton and below Pleasant Valley. Again, no well data are available but it appears that there should be fairly good opportunity of locating permeable beds at some depth in these localities.

Sand and gravel appears to be poorly developed in Mad River above Winsted, Conn. However, the valley leading southward from Robertsville on Still River through Winsted to Torrington was a spillway during the late glacial period and unconsolidated sediment is present there. A pocket of sediment around Robertsville, Conn. may favor small ground-water developments and some good ground-water development possibilities are inherent in the valley almost as far south as Winsted. South of Winsted the valley is somewhat broader and contains at least 90 feet of gravelly fill. Although the more than 5 mile reach below Winsted looks particularly promising for the development of high yield wells, total sustained pumpage would be limited by the amount of recharge available. Up to 1 mgd recharge per mile reach of valley might be counted upon in the southern part of the valley but nearer Winsted a maximum ground-water development would be supported by underflow from the south and a little more than 1 mgd might be available.

A small area of unconsolidated fill is present around Maple Hollow on the upper Nepaug (Torrington topographic sheet). It is thought that the thickness of the fill may be small here and the chance of developing more than a very few hundreds of gallons a minute is poor.

During the earlier stages of glacial melting the Farmington River below Collinsville was blocked by ice or glacial debris and the Farmington and

Nepaug Rivers flowed southward through Satans Kingdom (Collinsville topographic sheet), passed west of Nepaug Reservoir and on through Burlington and spilled southward into the Pequabuck valley around Bristol. Gravelly sediments are widely distributed in this broad channelway. It is not known, however, if thicknesses of sediments are present which would hold much water in storage and permit development of high yield wells.

Opposite Satans Kingdom the Farmington River flowed east of its present course. Deep lying deposits in the old channel may make possible the development of high yield wells here. However, the widespread kame terrace deposits seen in that area may lie largely above water level.

The small valley above Collinsville in which Cherry Brook flows is filled with unconsolidated sediment and, particularly below Canton Center, may be a favorable area for wells yielding a few hundred gallons a minute. The north-south Roaring Brook valley that enters the Farmington Valley proper at Unionville will probably lend itself to the development of several high yield wells, particularly south of the Canton Golf Course. Depth to bedrock is approximately 100 feet in the deeper parts of this channel (Randall, 1964a, p. 5). In the lower valley a sustained yield of about 1 mgd per mile of reach might be developed. Wells at the lower end of the valley would be sustained to some degree by underflow from the north.

The Farmington River, at a late stage of deglaciation, followed a spillway still lower than the one that passed through Burlington to the Pequabuck. With the ice still present in the low lying Plainville-Tariffville valley, the river passed southwestward at Unionville through the present

Lake Garda area (Bristol, Conn. topographic sheet) and into the Pequabuck drainage system. Coarse gravels should be present in this channel from place to place. Heavily pumped wells near the Farmington River developing water from deep strata might induce recharge from that river but elsewhere in this temporary channel large total ground-water discharge could not be sustained due to limited recharge. However, ample water for small housing developments could doubtless be developed without difficulty.

The Farmington River emerges from the highlands below Unionville into a broad open valley and at Farmington turns sharply northward, flows past Avon and Simsbury to Tariffville, Conn., where it again turns sharply, here eastward, through a gap in the basalt ridge to the low ground adjacent to the Connecticut River.

The broad valley extending from above Tariffville southward to Plainville and on to Long Island Sound was a pre-glacial valley, the bottom of which is known to be 231 feet below sea level just northeast of Simsbury and more than 100 feet below sea level in the Plainville area. Near Tariffville it is known to be more than 24 feet below sea level. Well records (Randall, 1964a, p. 10, 16) suggest that the pre-glacial Westfield River did not join the pre-glacial Farmington River via the Congamond Lakes area because bedrock is relatively high in the passes into the Farmington valley on either side of Manitook Mountain (Tariffville topographic sheet and Randall, 1946b, Plate 1). Late glacial drainage from the Westfield River system did flow southward through the Farmington valley for a time due to ice blockage in the central lowland and seaward through the Quinnipiac valley below Plainville. In so doing melt-water streams deposited large quantities of coarse sediments along the valleys walls and, as the ice diminished to a core in the valley axis, at lower and lower elevations. Randall (1964b, p. 59) points out that the ice core of the major valleys tended to linger and that when it finally melted fine sandy material (valley train deposits) filled in the gap. At this late stage streams had diminished in volume to something comparable to their present size, most of the coarse material that could be moved had already been transported and redeposited at lower level and, in a now less turbulent environment, streams carried in only finer grained sediment.

The problem then in the Farmington valley is to avoid the areas where thick sections of fine sediment are present and to locate wells where coarse sediments are present at not too shallow a depth. Relative to the present Farmington River, thick silty or clayey sections have been penetrated less than a mile north of the big bend of the river at Tariffville (Randall, 1964a), on the west bank of the river at Simsbury, east of the river at Weatogue, west of the river a mile south of Weatogue, along the river at the north edge of Farmington, and west of the Pequabuck River a mile south of Farmington. The area in the immediate vicinity of the Farmington River thus appears to be an area to avoid.

On the other hand coarse sediments at some little depth have been penetrated at Five Points which is a mile west of Manitook Mountain (Tariffville topographic sheet). At the south end of Manitook Lake sand, "mostly medium to coarse" that heaved badly, extended from the surface to bedrock at a depth of 147 feet. According to the driller the well could have been finished at almost any depth, presumably by installation of a screen followed by proper development. A mile west of Granby a domestic well on Barndoor Hills Road just south of State Highway 20 penetrated coarse sand from 40 to 75 feet and coarse gravel from 75 to 84 feet, at which depth the hole was discontinued. In a municipal well just southwest of Granby a yield of 510 gpm was obtained. This well is of particular interest in that water was developed in fine sand rather than coarse sand or gravel and further, the gravel pack type of construction was not employed. Twenty-slot screen was set from 77½ to 82½ feet and #30-slot from 82½ to 92½ feet. The 510 gpm yield was obtained with 38 feet of drawdown.

About two miles northwest of Tariffville all the material penetrated to a depth of 121 feet was water bearing. Coarse sand extends from 80 to 90 feet and "heavy gravel" with particle size in the one-half to three-quarter inch range extends from 90 to 121 feet. Over 1 mgd should be easily available here in a properly developed well. One mile west of Tariffville a well yields 1,200 gpm from coarse sand between 73 and 110 feet. However, in a second well close by fine sand and silt was encountered to a depth of 130 feet below which 45 feet of well sorted fine to coarse sand was present. Only 250 gpm was developed here. The dimensions of the screens installed in this well and the adjacent 1,200 gpm well are not known.

About two miles west-southwest of Simsbury, Conn., (Avon topographic sheet) a 60-foot well yielded 85 gpm with 2 feet of drawdown. Sandy gravel extended from 35 to 60 feet below the surface. In the valley west of Bushey Hill, that is, 3 miles west of Weatogue, a very small yield was obtained in a

55-foot well in which 4 feet of #100-slot screen was set at the base of a 15-foot thickness of gravel. This seems to be an obvious instance of failure to develop the well fully. Near West Avon (west of Thompson Hill) a 52-foot 12-inch diameter well drilled for the Avon Water Co. yielded 504 gpm with 28 feet of drawdown. Dirty gravel is reported just north of the Avon-Farmington town line close to Farmington River where fine clayey sediments might be expected.

In a well at River Glen, Conn., on the Farmington River (New Britain topographic sheet) gravel was present between depths of 20 and 66 feet. The driller considers that a yield of 1 mgd could be obtained here with proper screening and development. Considering the location of the well on the bank of Farmington River and the material penetrated, the drillers estimate seems very modest indeed. Making the highly reasonable assumption that recharge from the river would take place here under heavy pumping conditions and that the formation noted is present along a moderate reach of the river (a fraction of a mile), it would seem that 2 mgd or more might be obtained from a 18-inch diameter screened well developed by conventional methods ("gravel developed" rather than "gravel-packed", to use local terminology) and that several such wells might be constructed in the area without appreciable interference with one another.

Summarizing, the coarse permeable sediments (ice contact deposits) have been found along the main lines of drainage of glacial meltwater streams, generally west of the Farmington River, on higher ground than the terrace immediately adjacent to the river. These include the valleys on either side of Manitook Mountain that lead south through Granby, Conn. Below Granby the more important (?) channel is southwestward passing south of the Barndoor Hills through Hoskins to West Simsbury, Crowleys Corner and West Avon and, less importantly, from Granby through Hoskins and just west of Simsbury, Weatogue and Avon. These meltwater stream courses merged as they approached Plainville.

It should be possible to construct many high yield wells in the broad Farmington Valley which will sustain a yield of many millions of gallons a day. Perhaps 5 mgd could be developed northwest of Granby and over 1 mgd per linear mile in the channelway that passes close to the Barndoor Hills and southward through West Avon to River Glen on the Farmington, a distance of about 12 miles. A lesser quantity might be developed along the channel leading more directly southward from Granby somewhat west of the Farmington River without counting upon that river for recharge. However, if water will percolate through the fine grained sediments in and along the present bed of the Farmington River at a reasonably rapid rate to the coarse grained sediments supplying the wells the discharge that could be sustained would be reckoned in terms of perhaps 5 mgd per mile of valley reach, or more.

The Farmington River and the Pequabuck drained southward via the Quinnipiac valley in the earlier stages of deglaciation. Upon entering the lowland area below Unionville stream velocities were reduced and deposition of much of the stream load occurred. In the Plainville area the bed of the meltwater stream built up rapidly and ponded the waters in the north until these found an outlet through a pre-existing gap at Tariffville, after which downcutting proceeded fast enough to maintain the course of the Farmington

River in that direction. The writer suggests that a tilting of the southerly portion of the Connecticut basin toward the north as a result of relief of ice load may have contributed to the mechanism of reversal of drainage.

Be that as it may, much coarse sediment was deposited in the Plainville area. A 6-inch test well drilled for the city of New Britain, a mile northwest of Plainville (New Britain topographic sheet), obtained 520 gpm in a 60-hour pumping test from fine sand (?) at 110 to 120 feet and gravel at 120 to 130 feet. Gravel between 85 and 98 feet was not screened (Randall, 1964a, well F 123, p. 20). Four jetted 2-inch wells nearby penetrated sandy and gravelly material beneath silty beds in the 75 to 100 foot range and developed a yield of 125 gpm in each by suction. However, two other jetted nearby test wells encountered silt to 147 and 192 feet, according to the driller's logs. The full thickness of gravels beneath the fine beds was not explored in these wells. A jetted well on the Pequabuck one-fourth mile to the east penetrated 259 feet of silt and clay. The Plainville Water Co. developed 500 gpm with 19.3 feet of drawdown in a well equipped with 13 feet of screen. Clean medium sand extended from 60 to 65 feet, coarse sand with some pea gravel from 65 to 90 feet and medium sand from 90 to 95 feet in this well (La Sala and Meikle, 1964, p. 16). This well, of course, could yield 1 mgd without difficulty by utilizing a little more drawdown (almost 40 feet of additional drawdown is available)--or would probably yield 1 mgd with same drawdown if a longer screen were used.

Near the base of basalt mountain the city of Plainville has two wells. The one obtains 680 gpm with 13.7 feet of drawdown from a well in which

10 feet of #60 slot screen is placed at the base of a 24-foot thickness of coarse sand. The second well is nearby and is equipped with 10 feet of #80-slot screen placed at about the same depth. It yields 1,000 gpm with 20.3 feet of drawdown and is pumped at that rate on a 24-hour basis (LaSala and Meikle, 1964, p. 8). Fine as these results are, still higher yields would be obtained here by use of more screen.

A yield of 225 gpm with 15 feet of drawdown was developed from a 48-foot well in the center of the city of Plainville. At this shallow depth only fine sands were penetrated. It is worth noting, however, that worthwhile quantities of water can be produced from fine sand.

In the Pequabuck valley the city of Bristol (Bristol topographic sheet) has two wells in the valley bottom west of the city, one of which yields 800 gpm with 32 feet of drawdown, the other only 200 gpm (drawdown unknown). The higher yield well is fitted with 20 feet of 250-slot screen, the lower yield well with 10 feet each of 100-slot and 200-slot screen. In the valley northeast of the city an installation of 20 shallow 8-inch drilled wells and a caisson well provides up to 3.3 mgd to the city of Bristol. A ditch leads water from Polkville Brook and Mine Brook parallel to the line of wells and assures ample recharge. Somewhat to the west of the well battery mentioned two moderately shallow gravel wells each yield 300 gpm. They are fitted with 10 feet of 100-slot screen. Presumably larger slot size screens might have been used here advantageously. A $2\frac{1}{2}$-inch test well nearby equipped with 30-slot screen is reported to have yielded 60 gpm with only 1.3 feet of drawdown.

In the industrial section of town, several wells have been constructed that yield 300 to 400 gpm. Clogging of screens on these wells makes periodic cleaning necessary.

A great deal of test drilling has been carried out in the Bristol area. However, very few of the holes were continued to bedrock. Therefore, the fact that bedrock was found at rather shallow depths in a few places in the valley passing eastward through the city and in the north-south valley that enters the eastern part of Bristol does not mean that narrow deeper sediment filled channels do not exist that would yield larger supplies than have already been developed. The area immediately south of the city has also been incompletely explored.

Summarizing sub-basin X as a whole, large quantities of water may be available from place to place along the upper Farmington River and its tributaries where immediate infiltration from the major streams can be counted upon but more generally in the broad valley area extending from Granby through Plainville and around Bristol.

Small quantities of water are available in the valley passing through Winsted, in the valleys extending northward from Collinsville and Unionville. The ground water potential of the gravelly area extending from New Hartford to Burlington is thought to be poor.

The broad Farmington valley between the Western Highland and the trap ridges (Talcott Mountains), fine grained sediments with poor water-bearing qualities lie along Farmington River. In most instances coarse water-bearing sediments deposited by earlier more turbulent meltwater streams underlie the slightly higher ground back from the river. In the Granby-Plainville-Bristol area considerable additional ground water can be developed if properly constructed wells are located where geologic and hydrologic conditions are favorable.

Sub-basin Y

Area Y includes the drainage systems of Salmon River, Roaring Brook and Eight Mile River on the east bank of the Connecticut River below Middletown and a small area along the west bank drained by several minor streams. The Salmon River and Roaring Brook referred to in this sub-basin should not be confused with the two streams of the same name that are present below Manchester and which were referred to in discussion of sub-basin L-10.

The farthest north tributary of Salmon River is Blackledge River which originates east of Manchester. The valley of Blackledge River is generally narrow and there is little suggestion that much fill is present in that valley (Rockville and Marlborough, Conn., topographic sheets) in the upper ten-mile reach above its junction with Fawn Brook (Moodus, Conn., topographic sheet).

The somewhat shorter valley of Fawn Brook appears equally unpromising as far as development of ground water supplies is concerned but it is probably true that development of more than minimum domestic supplies can be better developed from sandy beds or from fractured rock immediately beneath the sandy beds in these valleys rather than on the hard rock hills and ridges.

For two miles below its junction with Fawn Brook the Blackledge River is a wide alluvial valley where a million or two gallons a day of ground water might be developed.

Salmon River heads up in the Columbia Lake area 8 miles northeast of its junction with Blackledge River. In most of that area the unconsolidated deposits appear to be thin and ground water prospects are poor. Along the short reach west of North Westchester considerable fill is present and ground water prospects are excellent both from point of view of unconsolidated sediments present as well as potential recharge. Depending upon the distribution of aquifers here, perhaps as much as 5 mgd of ground water might be developed.

Below its junction into Blackledge River, Salmon River flows through a narrow canyon like valley to the Connecticut River. Glacio-fluvial deposits are present on both sides of the valley, as far as could be determined, from the junction with Fawn Brook all the way downstream to the Connecticut River, a distance of eight miles, and it is thought the sediments seen may extend to some little depth below river level. That being the case, there should be ample opportunity to develop ground water supplies from wells close to the river. High yield wells there would, in effect, deliver filtered river water inasmuch as the volume of storage water in sediments is rather small. The total amount of water available then might be limited to that part of the low flow of Salmon River that would recharge the sediments when water levels are lowered by heavy pumping.

As noted, the valleys north of Colchester, Conn., (headwaters of Salmon River) seem to offer little possibility of developing ground water in quantity. In the general vicinity of Colchester, however, a wide area of fill is present from which ground water supplies should be available. The town of Colchester has a 58-foot well a half mile southwest of town that yields 430 gpm. Nearby is a domestic well which penetrated medium sand and gravel to a depth of 66½ feet. This well was completed in a gravelly stratum at 38 feet, probably as an open end well, and yields 70 gpm. The area along Meadow Brook northwestward from Colchester to its junction with Salmon River appears to be by far the best area for ground water development. Up to three million gallons a day could probably be developed with ease in the general vicinity of Colchester.

A 6-mile long swampy valley from Moodus Reservoir leads northward to Salmon River. North-flowing Pine Brook lies in the upper portion of this valley (Moodus topographic sheet). However, glacial meltwaters once flowed southward through this valley and into what is now Roaring Brook and subsequently into the Connecticut at Hadlyme (Deep River topographic sheet). Nothing is known of the depth and character of the fill in this old channel. The prospects for developing ground water there do not appear to be very good but perhaps a few hundred gallons a minute might be obtained from place to place along this 11-mile reach. Immediately east of Hadlyme a broader area of glacial deposits appears much more promising and probably more than a million gallons a day could be developed there without difficulty.

Along the short Moodus River that flows from Moodus Reservoir through Moodus to the Connecticut (Deep River topographic sheet) sandy beds are well exposed. However, several well records at hand and rock outcroppings along the river suggest that no deep channel exists here and that the development of more than minimum supplies of ground water may be difficult.

The valley of Eight Mile River once received glacial meltwaters passing southward thru Colchester and Lake Hayward as well as from Pine Brook above Moodus Reservoir. However, important accumulations of alluvium are seen where Lake Hayward Brook joins Eight Mile River (Hamburg topographic sheet) just north of Devils Hopyard State Park. Here perhaps, a million gallons a day of ground water might be developed. Downstream ground water prospects are negligible in the narrow valley through the park area but below the park the valley widens considerably and much unconsolidated sediment is present. Several million gallons a day might be developed in the lower 4-mile reach of the valley.

A broad area along upper East Branch of Eight Mile River may be susceptible to development of one or two million gallons a day of ground water.

Falls Brook and Beaver Brook, both of which flow into the lower course of Eight Mile River are laid in sediment filled valleys that seem worthy of exploration for development of up to two million gallons a day of ground water.

Valleys of Lieutenant River and Black Hall River lead southward to the estuary of the Connecticut River. Although no large quantity of water has been developed from glacial deposits in these areas it does not follow that alluvial aquifers are not present. Exploration holes in the unconsolidated sediment have not everywhere been continued to bedrock. In some instances finer grained aquifers more difficult to develop have been rejected as non-water-bearing. Elsewhere prime aquifers have been cased off and the well was completed in the underlying bedrock.

Ground water developments along the Sound and along the Connecticut as far upstream as Hadlyme should be planned in such a way as to avoid the possibility of contamination by salt or brackish water from the river or the sound. Domestic supplies can probably be obtained from wells along the lower Connecticut River and Long Island Sound but where more than small quantities are pumped there is the ever-present danger that salt or brackish water will be drawn into the well field.

On the western side of Connecticut River prospects for developing ground water in quantity are very poor. In the valley of Candlewood Hill Brook that passes through Higganum, Conn., (Haddam topographic sheet) a few widely spaced wells might develop as much as a million gallons a day but underground storage is limited and maintaining a high discharge in long periods of deficient rainfall may be difficult. Such ground water as could be developed here might best be used to relieve the draft on the nearby surface reservoir when the level of that reservoir falls below some pre-determined level. The area of unconsolidated sediment two miles south of Higganum might be productive of a small volume of ground water but any significant discharge would be, in effect, robbing water that ordinarily moves to Higganum Reservoir by surface or underground flow.

In the narrow crooked valley passing through Chester (Deep River topographic sheet) the fill of glacial sediment does not appear to be thick. Ground water prospects are thought to be very poor here.

The stream passing through Deep River drains a fairly large area to the south but it seems unlikely that a significant portion of the underground storage water there would be available to downstream wells in times of drought.

At Essex a 52-foot well on Falls River northeast of the center of town (Essex topographic sheet) has a yield of 290 gpm. The chance of sustaining such a yield or an even larger yield under continuous operating conditions seem excellent in that underground flow as well as surface flow from a rather large area to the west pass through a narrow valley in which the well is located. A low dam downstream on Falls River prevents the movement of brackish waters upstream to the well site.

The terrace areas opposite East Haddam and east of Chester may be productive of very large quantities of water if geologic conditions there are similar to those at the CANEL site upstream. Here, and particularly on the terrace east of Chester, the possibility of brackish water intrusion to heavily pumped wells at times of very low flow of Connecticut River should be considered.

Summarizing, prospects of developing moderate supplies of ground water are good in the Blackledge River drainage area west and northwest of North Westchester. The valley immediately west of Colchester appears to be very promising. The area just east of Hadlyme may be an excellent area for moderate ground water development.

Small supplies should be available north of Devils Hopyard along Eight-Mile River but prospects are better a few miles downstream.

Very little is known of the character and depth of fill in channels leading northward from Lieutenant and Black Hall Rivers. Exploration seems justified here where not more than a few million gallons a day is needed.

The area on the western side of the Connecticut River in this sub-basin will be productive of only very small supplies of ground water except perhaps in terrace areas bordering that river.

REFERENCES

1. Baker, J. A., Lang, S. M., and Thomas, M. P., 1965, Geology and hydrology of the Hartford Research Center CANEL site, Middletown, Connecticut: U.S. Geol. Survey Bull. 1133-G, 42 p.

2. Cushman, Robert V., 1964, Ground water resources of north central Connecticut: U.S. Geol. Survey WSP 1752, 96 p.

3. Cushman, R. V., Baker, John A., and Meikle, R. L., 1964, Records and logs of selected wells and test borings and chemical analyses of water in north central Connecticut: Conn. Water Resources Bull. No. 4, 27 p.

4. Flint, R. F., 1933, Late-Pleistocene sequences in the Connecticut valley: Geol. Soc. America Bull., v. 44, p. 965-988.

5. LaSala, Jr., A. M., 1964, Geology and ground-water resources of the Bristol-Plainville-Southington area, Connecticut: U.S. Geol. Survey WSP 5178, 70 p.

6. LaSala, Jr., A. M., and Meikle, R. L., 1964, Records and logs of selected wells and test borings and chemical analyses in the Bristol-Plainville-Southington area, Connecticut: Conn. Water Resources Bull. No. 5, 18 p.

7. Petersen, R. G., and Maevsky, Anthony, 1962, Records and logs of selected wells and test holes, records of selected springs, and chemical analyses of water in western Massachusetts: U.S. Geol. Survey open-file report, 31 p.

8. Randall, Allan D., 1964a, Records and logs of selected wells and test borings and chemical analyses in the Farmington-Granby area, Connecticut: Conn. Water Resources Bull. No. 3, 25 p.

9. Randall, Allan D., 1964b, Geology and ground water resources of the Farmington-Granby area, Connecticut: U.S. Geol. Survey WSP 1661, 129 p.